US006160810A

United States Patent [19]

Brodigan

[11] **Patent Number: 6,160,810**

[45] **Date of Patent: Dec. 12, 2000**

[54] **ATM BASED VDSL COMMUNICATION SYSTEM HAVING META SIGNALING FOR SWITCHING A SUBSCRIBER BETWEEN DIFFERENT DATA SERVICE PROVIDERS**

[75] Inventor: **Donald L. Brodigan**, Broomfield, Colo.

[73] Assignee: **Qwest Communications International Inc.**, Denver, Colo.

[21] Appl. No.: **09/339,148**

[22] Filed: **Jun. 24, 1999**

[51] **Int. Cl.**[7] **H04L 12/28**

[52] **U.S. Cl.** **370/395**; 370/397; 370/399

[58] **Field of Search** 370/395, 397, 370/399, 352

[56] **References Cited**

U.S. PATENT DOCUMENTS

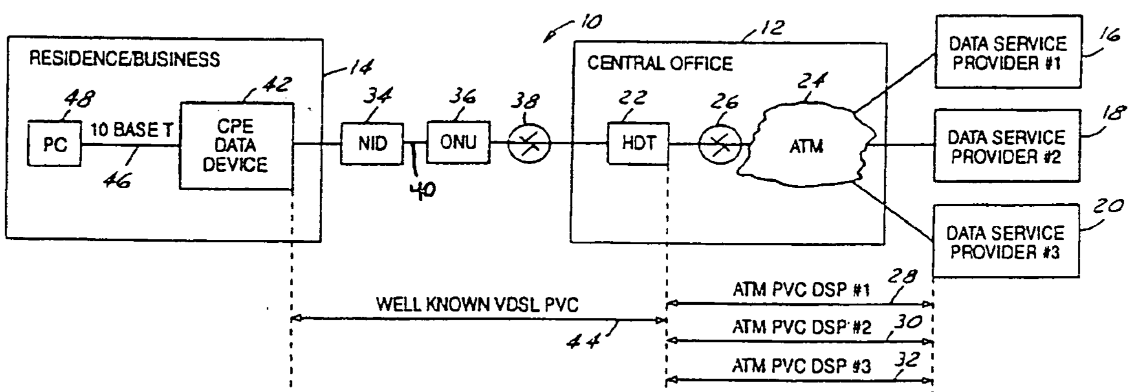
6,058,422	5/2000	Ayanoglu et al.	709/226
6,088,368	7/2000	Rubinstain et al.	370/480
6,101,182	8/2000	Sistanizadeh et al.	370/352

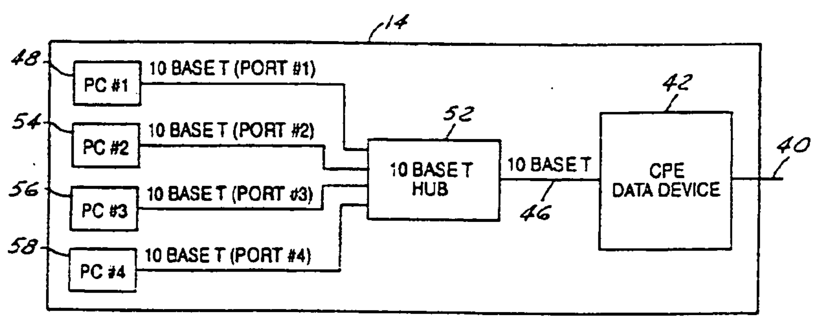
Primary Examiner—Chi H. Pham
Assistant Examiner—Brenda H. Pham
Attorney, Agent, or Firm—Brooks & Kushman P.C.

[57] **ABSTRACT**

An asynchronous transfer mode (ATM) based very-high-bit-rate digital subscriber line (VDSL) system for connecting a subscriber between different data service providers includes an ATM network connected to data service providers. A host digital terminal (HDT) is connected to the ATM network by an ATM permanent virtual circuit (PVC). Each of the ATM PVCs is associated with a corresponding one of the data service providers. The ATM PVCs connect the HDT to the data service providers. The HDT and the data service providers communicate data signals on the ATM PVCs through the ATM network. A customer provided equipment (CPE) data device is connected to the HDT by a VDSL PVC. The CPE device and the HDT communicate data signals on the VDSL PVC. A subscriber personal computer is connected to the CPE device for communicating data signals with the CPE device. The personal computer is operable to generate a channel signal corresponding to a selected one of the data service providers. The HDT, in response to the channel signal, connects the ATM PVC associated with the selected data service provider with the DSL PVC to establish a system PVC connecting the selected data service provider with the personal computer. The selected data service provider and the personal computer communicate the data signals on the system PVC.

18 Claims, 2 Drawing Sheets





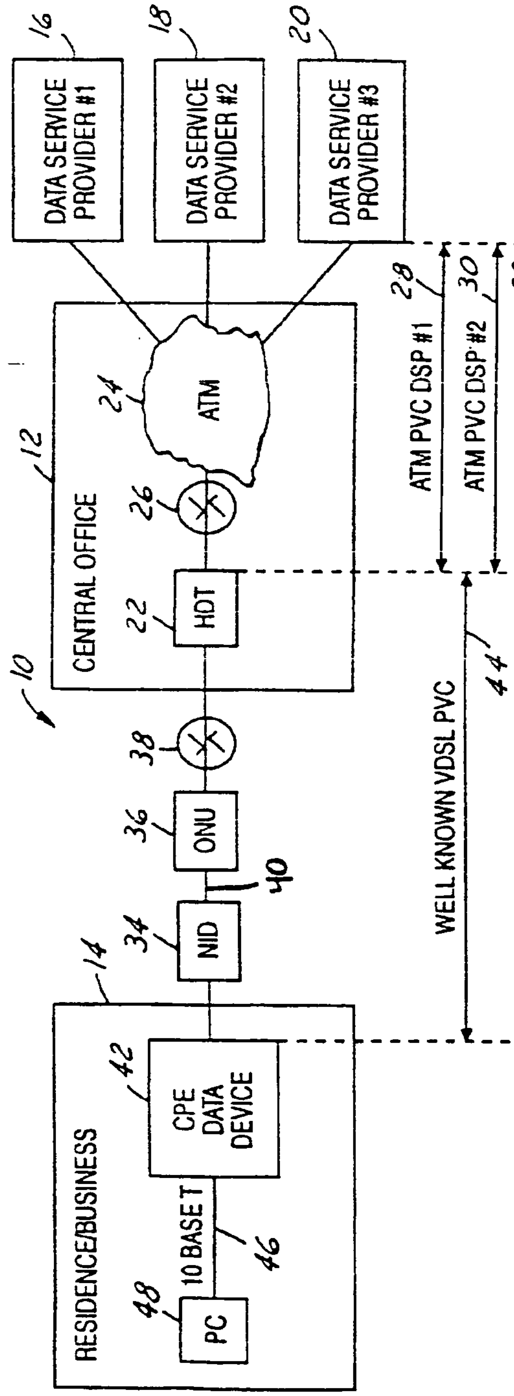


FIG. 1

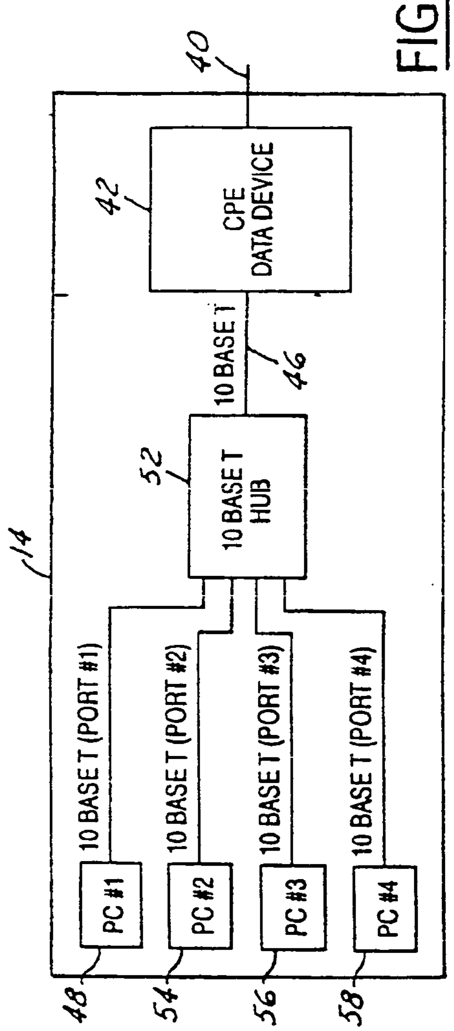


FIG. 3

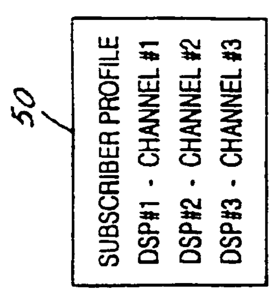
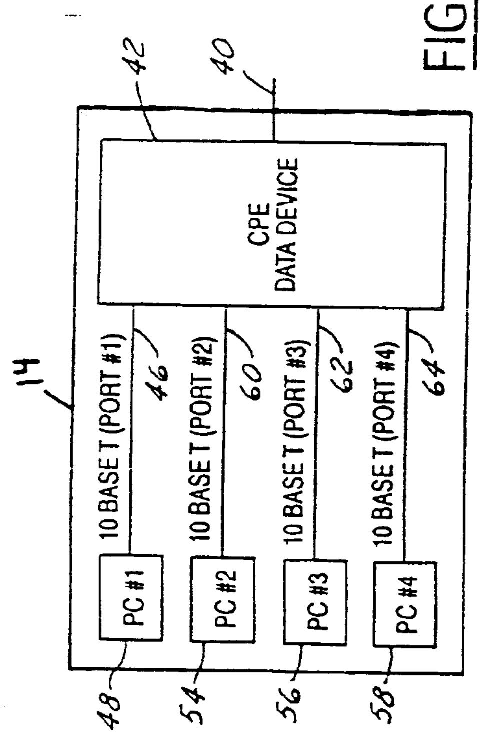
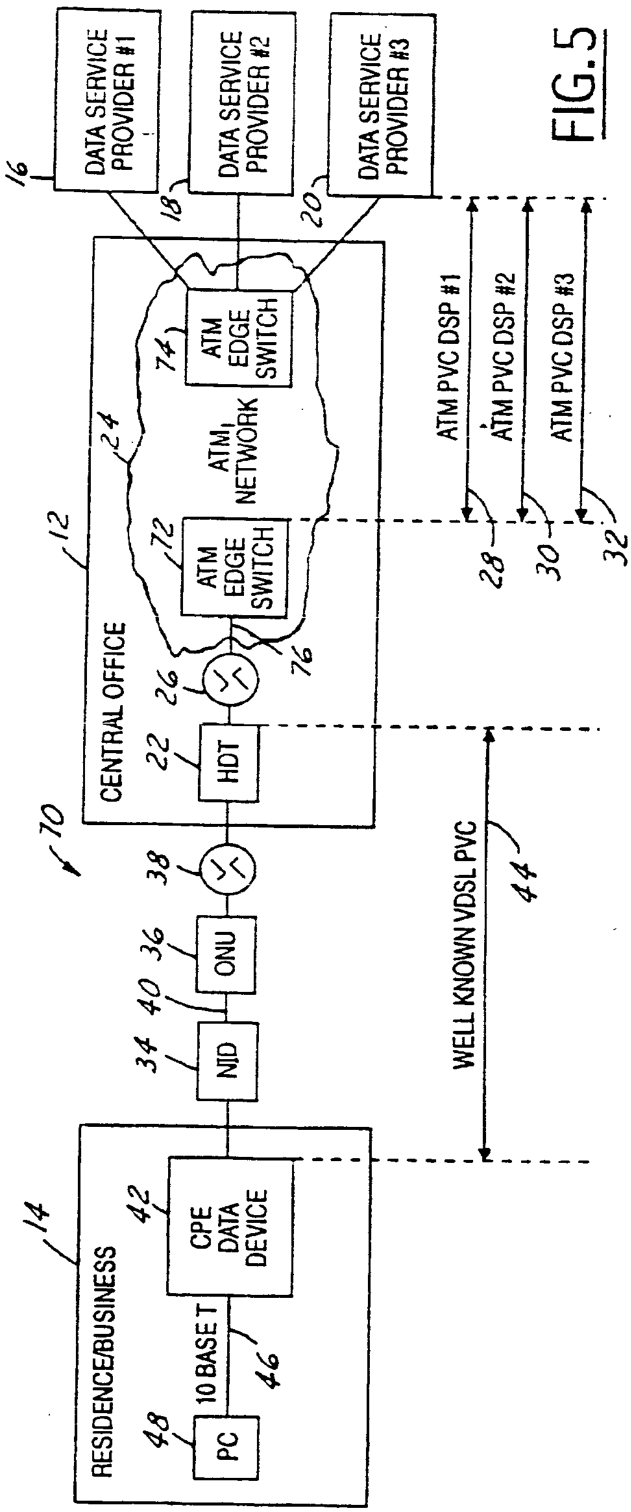


FIG. 2



CPE
DATA DEVICE
10 BASE T (PORT #1)
10 BASE T (PORT #2)
10 BASE T (PORT #3)
10 BASE T (PORT #4)
PC #1
PC #2
PC #3
PC #4
14
40
42
46
60
62
64
48
54
56
58

FIG. 4



DATA SERVICE PROVIDER #1
DATA SERVICE PROVIDER #2
DATA SERVICE PROVIDER #3
ATM EDGE SWITCH
ATM NETWORK
ATM EDGE SWITCH
CENTRAL OFFICE
HDT
ONU
NID
CPE DATA DEVICE
10 BASE T
PC
RESIDENCE/BUSINESS
ATM PVC DSP #1
ATM PVC DSP #2
ATM PVC DSP #3
WELL KNOWN VDSL PVC
16
18
20
74
24
72
12
26
76
22
70
38
36
40
34
14
42
46
48
28
30
32
44

FIG. 5

ATM BASED VDSL COMMUNICATION SYSTEM HAVING META SIGNALING FOR SWITCHING A SUBSCRIBER BETWEEN DIFFERENT DATA SERVICE PROVIDERS

TECHNICAL FIELD

The present invention relates generally to asynchronous transfer mode (ATM) based very-high-bit-rate digital subscriber line (VDSL) communication systems for providing data services and, more particularly, to an ATM based VDSL communication system having meta signaling for switching a subscriber to different data service providers via a single twisted pair drop connected to the subscriber.

BACKGROUND ART

An asynchronous transfer mode (ATM) based very-high-bit-rate digital subscriber line (VDSL) communication system includes an ATM network connected to a host digital terminal. The ATM network and the host digital terminal connect a data service provider to a subscriber over a system permanent virtual circuit (PVC). The data service provider provides services to the subscriber over the system PVC. The system PVC is a direct connection between the data service provider and the subscriber running through the ATM network and the host digital terminal. The system PVC consists of an ATM PVC between the data service provider and the ATM network and a VDSL PVC between the host digital terminal and the subscriber. The host digital terminal connects the ATM PVC and the VDSL PVC to establish the system PVC between the data service provider and the subscriber.

If the subscriber wishes to receive services from a second data service provider, the ATM based VDSL communication systems connects the second data service provider and the subscriber over a second system PVC. The second system PVC is a direct connection between the second data service provider and the subscriber running through the ATM network and the host digital terminal. The second system PVC consists of a second ATM PVC between the second data service provider and the ATM network and a second VDSL PVC between the host digital terminal and the subscriber. The host digital terminal connects the second ATM PVC with the second VDSL PVC to establish the second system PVC between the second data service provider and the subscriber.

A problem with having multiple system PVCs directly connecting data service providers with a subscriber is that a VDSL PVC is required for each system PVC. This is a problem because many subscriber residences and businesses only have one twisted pair link or drop which can only support one VDSL PVC to the host digital terminal. Thus, a subscriber can only be directly connected to one data service provider. Adding more twisted pair links for supporting multiple VDSL PVCs requires a massive undertaking and, in any event, multiple VDSL PVCs to the host digital terminal would consume the host digital terminal resources.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an asynchronous transfer mode (ATM) based very-high-bit-rate digital subscriber line (VDSL) communication system having meta signaling for switching a subscriber between different data service providers via a single twisted pair drop connected to the subscriber.

It is another object of the present invention to provide an ATM based VDSL communication system in which a sub-

scriber can select a data service provider from a plurality of data service providers to connect an ATM PVC associated with the selected data service provider with a VDSL PVC of the subscriber to establish a system PVC connecting the subscriber and the selected data service provider.

It is a further object of the present invention to provide an ATM based VDSL communication system in which data service providers are switched to be individually connected to a VDSL PVC of a subscriber for connection to the subscriber.

In carrying out the above objects and other objects, the present invention provides an asynchronous transfer mode (ATM) based very-high-bit-rate digital subscriber line (VDSL) communication system for connecting a subscriber between different data service providers. The ATM based VDSL communication system includes an ATM network connected to a plurality of data service providers. A host digital terminal is connected to the ATM network by one of a plurality of ATM permanent virtual circuits. Each of the ATM permanent virtual circuits is associated with a corresponding one of the plurality of data service providers and is supported on a fiber optics link. The plurality of ATM permanent virtual circuits connect the host digital terminal to the plurality of data service providers. The host digital terminal and the plurality of data service providers communicate data signals on the plurality of ATM permanent virtual circuits through the ATM network. An optical network unit is connected to the host digital terminal by a fiber optics link.

A customer provided equipment (CPE) data device is connected through the optical network unit to the host digital terminal by a well known VDSL permanent virtual circuit. The well known VDSL permanent virtual circuit is supported on a fiber optics link between the host digital terminal and the optical network unit and a twisted pair drop between the optical network unit and the CPE data device. The CPE data device and the host digital terminal communicate data signals on the well known VDSL permanent virtual circuit. A subscriber personal computer is connected to the CPE data device for communicating data signals with the CPE data device. The subscriber personal computer is operable to generate a channel signal corresponding to a selected one of the plurality of data service providers. The host digital terminal, in response to the channel signal, connects the ATM permanent virtual circuits associated with the selected one of the data service providers with the well known VDSL permanent virtual circuit to establish a system PVC connecting the selected data service provider with the subscriber personal computer. The selected one of the data service providers and the subscriber personal computer communicate the data signals on the system PVC.

Further, in carrying out the above objects and other objects, the present invention provides another ATM based VDSL communication system for connecting a subscriber between different data service providers. This ATM based VDSL communication system differs from the ATM based VDSL communication system described above by including an ATM network having first and second ATM edge switches. The first ATM edge switch is connected to the plurality of data service providers and the host digital terminal is connected to the second ATM edge switch of the ATM network by one of the plurality of ATM permanent virtual circuits.

The above objects and other objects, features, and advantages of the present invention will be apparent from the following detailed description of the best mode for carrying out the invention when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 illustrates an ATM based VDSL communication system in accordance with a preferred embodiment of the present invention;

FIG. 2 illustrates a subscriber profile database contained in a host digital terminal of the ATM based VDSL communication system illustrated in FIG. 1;

FIG. 3 illustrates a 10baseT hub connecting multiple PCs to the CPE data device of the ATM based VDSL communication system illustrated in FIG. 1;

FIG. 4 illustrates multiple PCs connected directly by 10baseT ports to the CPE data device of the ATM based VDSL communication system illustrated in FIG. 1; and

FIG. 5 illustrates an ATM based VDSL communication system in accordance with an alternate embodiment of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Referring now to FIG. 1, an asynchronous transfer mode (ATM) based very-high-bit-rate digital subscriber line (VDSL) communication system 10 in accordance with a preferred embodiment of the present invention is shown. ATM is a high bandwidth, low-delay, connection-oriented, packet-like switching and multiplexing technique. ATM transmissions are cell-based, with cells having a fixed length. Information is presented to the network asynchronously. However, the switches and interlinking transmission facilities are synchronized. Of course, it is to be appreciated that the term "asynchronous transfer mode" as used herein is meant to encompass equivalent network architectures in addition to traditional ATM.

VDSL services are of particular interest for a hybrid local loop scenario. In particular, communication system 10 is suitable for fiber-to-the-neighborhood (FTTN), fiber-to-the-curb (FTTC), and fiber-to-the-home (FTTH) distribution. The various distribution formats are collectively referred to as FTTX. Communication system 10 generally provides a private line like connection between a subscriber and a data service provider selected from a plurality of data service providers.

Communication system 10 includes a central office 12 connecting a subscriber 14 such as a residence or business to a selected data service provider DSP 16, 18, and 20. Central office 12 includes a host digital terminal (HDT) 22 and an ATM network 24 connected together by a fiber optics link 26. Each of data service providers 16, 18, and 20 includes an ATM switch (not specifically shown) for connecting to central office 12 via ATM network 24. Each of data service providers 16, 18, and 20 transmit and receive data signals to and from central office 12. Central office 12 transmits and receives these data signals to and from subscriber 14.

An ATM PVC 28 connects HDT 22 to data service provider 16 through ATM network 24. Data service provider 16 communicates with central office 12 through ATM PVC 28. HDT 22 selects ATM PVC 28 from a pool of available PVCs for data service provider 16. Data service provider 16 has its own service handle assigned to its ATM PVC termination at the HDT. A service handle identifies the data rates that the ATM PVC can handle. For instance, 256 Kbps or 1 Mbps. HDT 22 maintains the ATM parameters associated with ATM PVC 28. ATM PVC 28 can have various cell and bit rates such as constant bit rate (CBR), variable bit rate (VBR), available bit rate (ABR), and unspecified bit rate (UBR) which are maintained in a database of HDT 22. Using ATM PVC 28 allows data service provider 16 to control its own service applications, Internet Protocol (IP) addresses, and security issues transparently to the VDSL network connecting subscriber 14 to HDT 22.

Similarly, an ATM PVC 30 connects HDT 22 to data service provider 18 through ATM network 24 and an ATM PVC 32 connects the HDT to data service provider 20 through the ATM network. Like ATM PVC 28, ATM PVCs 30 and 32 have associated ATM parameters and data service providers 18 and 20 control their own service applications, Internet Protocol (IP) addresses, and security issues transparently to the VDSL network connecting subscriber 14 to HDT 22. In general, each data service provider 16, 18, and 20 has its own ATM PVC for communication with HDT 22.

Central office 12 and subscriber 14 communicate using VDSL through a network interface device (NID) 34 and an optical network unit (ONU) 36. A fiber optics link 38 connects HDT 22 to ONU 36. HDT 22 can support typically up to sixty four ONUs. ONU 36 converts optical signals to electronic signals to communicate with NID 34 via a twisted pair drop 40. ONU 36 can support typically up to thirty two drops. NID 34 connects to a customer provided equipment (CPE) data device 42 of subscriber 14. HDT 22 of central office 12 and CPE data device 42 of subscriber 14 communicate though a well known PVC 44 having a virtual path identifier (VPI) and a virtual channel identifier (VCI). Well known PVC 44 is a digital subscriber line (DSL) for HDT 22 and CPE data device 42 to communicate using VDSL. HDT 22 connects well known VDSL PVC 44 with one of ATM PVCs 28, 30, and 32 to establish a private line like connection, i.e., a system PVC, between subscriber 16 and the respective one of data service providers 16, 18, and 20.

CPE data device 42 has a 10baseT port 46 for communicating with a subscriber personal computer (PC) 48. 10baseT port 46 is associated with well known VDSL PVC 44. PC 48 transmits and receives data signals to and from CPE data device 42 through 10baseT port 46 for communication with a selected one of data service providers 16, 18, and 20. Data service providers 16, 18, and 20 are data information service providers such as America Online, Microsoft Network, corporate local access networks (LAN), etc. Data service providers 16, 18, and 20 communicate with PC 48 to provide data information services to subscriber 14. Communication with a selected one of data service providers 16, 18, and 20 takes place through the system PVC consisting of well known VDSL PVC 44 and the respective one of ATM PVCs 28, 30, and 32. PC has its own Internet Protocol (IP) address which is used by data service providers 16, 18, and 20 for communicating with PC 48.

Generally, one of data service providers 16, 18, and 20 are individually connected to PC 48 to transmit and receive data signals with PC 48 along a system PVC. For instance, subscriber 14 and data service provider 16 may be connected by a system PVC consisting of well known VDSL PVC 44 and ATM PVC 28. Well known VDSL PVC 44 connects PC 48 to HDT 22 and ATM PVC 28 connects data service provider 16 to HDT 22. HDT 22 then performs soft PVC switching to connect well known VDSL PVC 44 with ATM PVC 28 to establish the system PVC connecting PC 48 and data service provider 16. PC 48 may request data service provider 16 to provide data information such as a sports web page. In response, data service provider 16 provides PC 48 with access to the sports web page. PC 48 may then request different information from data service provider 16 such as a business web page. Data service provider 16 then provides PC 48 with access to the business web page. All of this

communication between subscriber **14** and data service provider **16** takes place along the system PVC consisting of well known VDSL PVC **44** and ATM PVC **28**.

Referring now to FIG. 2 with continuing reference to FIG. 1. HDT **22** includes a subscriber profile database **50**. Subscriber profile database **50** contains a list of data service providers that subscriber **14** is entitled to receive data services. Each list of data service providers are associated with well known VDSL PVC **44**. Each data service provider contained in database **50** has an associated channel. For instance, data service provider **16** is associated with channel one; data service provider **18** is associated with channel two; and data service provider **20** is associated with channel three. Each channel is associated with a respective ATM PVC **28**, **30**, and **32** connecting the associated data service provider **16**, **18**, and **20** to HDT **22**. Each channel can be set to different data rates as the ATM parameters associated with ATM PVCs **28**, **30**, and **32** can be set accordingly.

Subscriber **14** can select to be connected from data service provider **16** to a different data service provider such as data service provider **18** by issuing a channel change request signal from PC **48** to CPE data device **42**. The channel change request signal contains a designation to select channel two corresponding to data service provider **18**. The channel change request signal includes the private IP address of CPE data device **42**. CPE data device **42** intercepts the channel change request signal based on identifying its IP address before the channel change request signal is placed in well known VDSL PVC **44** for transmission to HDT **22**. CPE data device **42** changes the channel change request signal to a standard digital storage media-command and control (DSM-CC) channel change request containing a channel two designation for data service provider **18** and an indication that PC **48** is requesting data service. HDT **22** of central office **12** receives the DSM-CC channel change request for data service with channel two designation, i.e., data service provider **18**. HDT **22** then accesses database **50** to determine whether subscriber **14** is eligible to receive data services from data service provider **18**. If so, HDT **22** then performs soft switching to replace ATM PVC **28** with ATM PVC **30** for connection to well known VDSL PVC **44** thereby establishing a second system PVC between data service provider **18** and subscriber **14** in place of the first system PVC between data service provider **16** and the subscriber. A third system PVC between data service provider **20** and subscriber **14** is established similarly after PC **48** issues another channel change request signal containing a designation to select channel three corresponding to data service provider **20**.

In operation, subscriber **14** wishes to subscribe to multiple data service providers **16**, **18**, and **20** to receive data services from the data service providers. Each of data service providers **16**, **18**, and **20** has a data service handle assigned to its respective ATM PVC **28**, **30**, and **32** connection to HDT **22**. The service handle is added to the subscriber's profile in database **50** in the same manner as a video channel is added to a subscriber video entitlement profile. Subscriber **14** then powers on CPE data device **42**. CPE data device **42** then transmits a sign on request over a meta signaling channel to HDT **22** through well known VDSL PVC **44**. HDT **22** then sets up a default system PVC between CPE data device **42** and data service provider **16**. This system PVC consists of well known VDSL PVC **44** and ATM PVC **28** and is like a private line from subscriber **14** and data service provider **16**. At this point, data is transferred between PC **48** via 10baseT port **46** to CPE data device **42**. CPE data device **42** transmits the data to HDT **22** over well known VDSL PVC **44** for transmission to data service provider **16** over ATM PVC **28**.

CPE data device **42** has a well known private IP address. If subscriber **14** wants to connect to data service provider **18** then the subscriber transmits from PC **48** a simple channel change request to CPE data device **42**. CPE data device **42** changes this request to a standard DSM-CC channel change data signal containing channel two designation and then transmits the DSM-CC channel change data signal over a meta signaling channel to HDT **22**. In response, HDT **22** replaces ATM PVC **28** with ATM PVC **30** to connect data service provider **18** to subscriber **14** over a new system PVC.

Referring now to FIG. 3 with continuing reference to FIG. 1, subscriber **14** includes a 10baseT hub **52** connecting first, second, third, and fourth PCs **48**, **54**, **56**, and **58** to CPE data device **42**. 10baseT hub **52** enables multiple PCs to communicate with selected data service providers over a common twisted pair drop **40**. Each of PCs **48**, **54**, **56**, and **58** have a unique media access control (MAC) address. The MAC address is like a serial number that allows the data service providers to track PCs **48**, **54**, **56**, and **58** to a specific installed location. Each of PCs **48**, **54**, **56**, and **58** can request a connection to a data service provider and then request a switch to a different data service provider if desired. Each of PCs **48**, **54**, **56**, and **58** have an application programming interface (API) to recognize the channel change requests from other PCs and handle its own session accordingly and to reestablish its session with its data service provider by automatically transmitting a channel change request.

Referring now to FIG. 4 with continuing reference to FIG. 1, subscriber **14** includes a CPE data device **42** configured for supporting multiple 10baseT ports **46**, **60**, **62**, and **64**. PCs **48**, **54**, **56**, and **58** are connected to CPE data device **42** via a respective 10baseT port **46**, **60**, **62**, and **64**. Each of 10baseT ports **46**, **60**, **62**, and **64** has an associated well known VDSL PVC for transmission to central office **12** over twisted pair drop **40**. Each of 10baseT ports **46**, **60**, **62**, and **64** has its own data service provider default channel assigned. When one of 10baseT ports **46**, **60**, **62**, and **64** receives a channel change request signal from its respective PC **48**, **54**, **56**, and **58**, CPE data device **42** transmits a DSM-CC channel change request to HDT **22**. This DSM-CC channel change request includes information identifying the 10baseT port (port #1, port #2, port #3, or port #4). The ATM PVC associated with the 10baseT port selecting a channel change request will be switched to the ATM PVC connecting the selected data service provider to HDT **22**. Multiple 10baseT ports provide a physical secure separation link between PCs. For instance, PC **48** may be connected to the Internet, PC **54** may be connected to a corporate network, PC **56** may be connected to an alarm service company, and PC **58** may be connected to a utility.

In general, by providing a way to switch using meta signaling switching the soft PVC at HDT **22**, the subscriber IP addressing is controlled by subscriber **14** and data service providers **16**, **18**, and **20** making the VDSL network ATM transport transparent to public and private IP addresses allowing private line like access between the subscriber and the data service providers.

Referring now to FIG. 5, an ATM based VDSL communication system **70** in accordance with an alternate embodiment of the present invention is shown. Communication system **70** has many of the same elements as communication system **10** and like elements have the same reference numerals. Communication system **70** generally differs from communication system **10** in that ATM network **24** includes ATM edge switches **72** and **74** for providing ATM local access network (LAN) switching to multiple data service providers **16**, **18**, and **20** using soft PVC on ATM network **24**

to direct TCP/IP (Transmission Control Protocol/Internet Protocol) traffic to the destination data service provider. ATM edge switch 72 connects ATM network 24 to HDT 22 and ATM edge switch 74 connects data service providers 16, 18, and 20 to the ATM network. In general, communication system 70 provides an additional switching function than communication system 10.

Initially, a first soft PVC is established by HDT 22 as described above with reference to FIG. 1. By establishing a network PVC pool 76 connected to ATM edge switch 72 which supports LAN switching, a second soft PVC will be established over ATM network 24 to the data service provider 16, 18, and 20 assigned to that IP address. Subscriber 14 has complete control of the ATM PVC. If subscriber 14 wishes to connect to another data service provider 16, 18, and 20, then the subscriber transmits a TCP/IP packet to ATM edge switch 72 with the IP address of the selected data service provider. ATM network 24 then terminates the PVC from the current data service provider and establish the PVC to the selected data service provider. If CPE data device 42 is powered off for any reason, the soft PVC at HDT 22 will be disconnected from ATM edge switch 72 and ATM edge switch 72 will be signaled to disconnect the PVC over the ATM network. In general, communication system 70 enables subscriber 14 to establish and switch calls based on ATM Layer 3 IP addressing and maintain the secure ATM virtual path to many different data service providers.

Thus, it is apparent that there has been provided, in accordance with the present invention, an ATM based VDSL communication system for switching a subscriber between different data service providers that fully satisfies the objects, aims, and advantages set forth above. While the present invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications, and variations will be apparent to those skilled in the art in light of the foregoing description. Accordingly, it is intended to embrace all such alternatives, modifications, and variations as fall within the spirit and broad scope of the appended claims.

What is claimed is:

1. An asynchronous transfer mode (ATM) based very-high-bit-rate digital subscriber line (VDSL) communication system for connecting a subscriber between different data service providers, the ATM based VDSL communication system comprising:

an ATM network connected to a plurality of data service providers;

a host digital terminal connected to the ATM network by one of a plurality of ATM permanent virtual circuits, each of the ATM permanent virtual circuits associated with a corresponding one of the plurality of data service providers and being supported on a fiber optics link, wherein the plurality of ATM permanent virtual circuits connect the host digital terminal to the plurality of data service providers, the host digital terminal and the plurality of data service providers communicating data signals on the plurality of ATM permanent virtual circuits through the ATM network;

an optical network unit connected to the host digital terminal by a fiber optics link;

a customer provided equipment (CPE) data device connected through the optical network unit to the host digital terminal by a well known VDSL permanent virtual circuit, the well known VDSL permanent virtual circuit being supported on a fiber optics link between the host digital terminal and the optical network unit and a twisted pair drop between the optical network unit and the CPE data device, the CPE data device and the host digital terminal communicating data signals on the well known VDSL permanent virtual circuit; and

a subscriber personal computer connected to the CPE data device for communicating data signals with the CPE data device, wherein the subscriber personal computer is operable to generate a channel change signal corresponding to a selected one of the plurality of data service providers;

wherein the host digital terminal, in response to the channel change signal, connects the ATM permanent virtual circuit associated with the selected one of the data service providers with the well known VDSL permanent virtual circuit to establish a system PVC connecting the selected one of the data service providers with the subscriber personal computer, wherein the selected one of the data service providers and the subscriber personal computer communicate the data signals on the system PVC.

2. The ATM based VDSL communication system of claim 1 wherein:

the host digital terminal, upon receiving another channel change signal corresponding to a second data service provider, disconnects the well known VDSL PVC from the ATM permanent virtual circuit associated with the current one of the plurality of data service providers and connects the well known VDSL PVC with the ATM permanent virtual circuit associated with the second data service provider to establish a second system PVC.

3. The ATM based VDSL communication system of claim 1 wherein:

the host digital terminal includes a database of the data service providers in which the subscriber personal computer has access, wherein the host digital terminal, in response to the channel change signal, processes the database to determine if the subscriber personal computer has access to the selected one of the plurality of data service providers and, if the subscriber personal computer has access, connects the ATM permanent virtual circuit associated with the selected one of the data service providers with the well known VDSL permanent virtual circuit to establish a new system PVC.

4. The ATM based VDSL communication system of claim 1 wherein:

the CPE data device, in response to the channel change signal from the subscriber personal computer, transmits a digital storage media-command and control (DSM-CC) signal on the well known VDSL PVC to the host digital terminal, the DSM-CC signal containing a designation indicative of the selected one of the plurality of data service providers.

5. The ATM based VDSL communication system of claim 4 wherein:

the CPE data device transmits the DSM-CC signal to the host digital terminal over a meta signaling channel on the well known VDSL PVC.

6. The ATM based VDSL communication system of claim 1 wherein:

the CPE data device has an Internet Protocol (IP) address, wherein the channel change signal includes the IP address of the CPE data device, wherein the CPE data device intercepts the channel change signal based on identifying its IP address and then transmits a digital storage media-command and control (DSM-CC) signal

on well known VDSL PVC to the host digital terminal, the DSM-CC signal containing a designation indicative of the selected one of the plurality of data service providers.

7. The ATM based VDSL communication system of claim 1 wherein:

each of the ATM permanent virtual circuits have associated ATM parameters.

8. The ATM based VDSL communication system of claim 1 wherein:

the subscriber personal computer and the CPE data device are connected by a 10baseT port.

9. The ATM based VDSL communication system of claim 1 further comprising:

a subscriber computer device; and

a 10baseT hub connecting the subscriber personal computer and the subscriber computer device via respective 10baseT device ports, the 10baseT hub being connected to the CPE data device via a 10baseT hub port.

10. The ATM based VDSL communication system of claim 1 further comprising:

a subscriber computer device, wherein the subscriber personal computer and the subscriber computer device are connected to the CPE data device by 10baseT ports, wherein each of the 10baseT ports has an associated well known VDSL PVC connected to the host digital terminal.

11. An asynchronous transfer mode (ATM) based very-high-bit-rate digital subscriber line (VDSL) communication system for connecting a subscriber between different data service providers, the ATM based VDSL communication system comprising:

an ATM network having first and second ATM edge switches, the first ATM edge switch connected to a plurality of data service providers;

a host digital terminal connected to the second ATM edge switch of the ATM network by one of a plurality of ATM permanent virtual circuits, each of the ATM permanent virtual circuits associated with a corresponding one of the plurality of data service providers and being supported on a fiber optics link, wherein the plurality of ATM permanent virtual circuits connect the host digital terminal to the plurality of data service providers, the host digital terminal and the plurality of data service providers communicating data signals on the plurality of ATM permanent virtual circuits through the ATM network;

an optical network unit connected to the host digital terminal by a fiber optics link;

a customer provided equipment (CPE) data device connected through the optical network unit to the host digital terminal by a well known VDSL permanent virtual circuit, the well known VDSL permanent virtual circuit being supported on a fiber optics link between the host digital terminal and the optical network unit and a twisted pair drop between the optical network unit and the CPE data device, the CPE data device and the host digital terminal communicating data signals on the well known VDSL permanent virtual circuit; and

a subscriber personal computer connected to the CPE data device for communicating data signals with the CPE data device, wherein the subscriber personal computer is operable to generate a channel change signal corresponding to a selected one of the plurality of data service providers;

wherein the host digital terminal, in response to the channel change signal, connects the ATM permanent virtual circuit associated with the selected one of the data service providers with the well known VDSL permanent virtual circuit to establish a system PVC connecting the selected one of the data service providers with the subscriber personal computer, wherein the selected one of the data service providers and the subscriber personal computer communicate the data signals on the system PVC.

12. The ATM based VDSL communication system of claim 11 wherein:

the host digital terminal, upon receiving another channel change signal corresponding to a second data service provider, disconnects the well known VDSL PVC from the ATM permanent virtual circuit associated with the current one of the plurality of data service providers and connects the well known VDSL PVC with the ATM permanent virtual circuit associated with the second data service provider to establish a second system PVC.

13. The ATM based VDSL communication system of claim 11 wherein:

the host digital terminal includes a database of the data service providers in which the subscriber personal computer has access, wherein the host digital terminal, in response to the channel change signal, processes the database to determine if the subscriber personal computer has access to the selected one of the plurality of data service providers and, if the subscriber personal computer has access, connects the ATM permanent virtual circuit associated with the selected one of the data service providers with the well known VDSL permanent virtual circuit to establish a new system PVC.

14. The ATM based VDSL communication system of claim 11 wherein:

the CPE data device, in response to the channel change signal from the subscriber personal computer, transmits a digital storage media-command and control (DSM-CC) signal on the well known VDSL PVC to the host digital terminal, the DSM-CC signal containing a designation indicative of the selected one of the plurality of data service providers.

15. The ATM based VDSL communication system of claim 14 wherein:

the CPE data device transmits DSM-CC signal to the host digital terminal over a meta signaling channel on the well known VDSL PVC.

16. The ATM based VDSL communication system of claim 11 wherein:

each of the ATM permanent virtual circuits have associated ATM parameters.

17. The ATM based VDSL communication system of claim 11 wherein:

the subscriber personal computer and the CPE data device are connected by a 10baseT port.

18. The ATM based VDSL communication system of claim 11 further comprising:

a subscriber computer device; and

a 10baseT hub connecting the subscriber personal computer and the subscriber computer device via respective 10baseT device ports, the 10baseT hub being connected to the CPE data device via a 10baseT hub port.

* * * * *

US006335936B1

(12) United States Patent
Bossemeyer, Jr. et al.

(10) Patent No.: US 6,335,936 B1
(45) Date of Patent: Jan. 1, 2002

E

(54) WIDE AREA COMMUNICATION NETWORKING

(75) Inventors: **Robert Wesley Bossemeyer, Jr.**, St. Charles, IL (US); **Dale Brian Halling**, Colorado Springs, CO (US); **Scott Christopher Goering**, Naperville, IL (US); **Michael George Gorman**, Schaumburg, IL (US); **Denise Violetta Kagan**, Riverwoods, IL (US); **Jeffrey Neumann**, Hoffman Estates, IL (US); **Michael Steven Pickard**, Highland Park, IL (US); **Michael Tisiker**, Westland, MI (US); **Bruce Edward Stuckman**, Algonquin, IL (US)

(73) Assignee: **Ameritech Corporation**, Hoffman Estates, IL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/296,954**

(22) Filed: **Apr. 22, 1999**

(51) **Int. Cl.**[7] **H04L 12/56**

(52) **U.S. Cl.** **370/420**; 370/467; 370/468; 370/485

(58) **Field of Search** 370/395, 397, 370/401, 409, 419, 420, 463, 465, 466, 467, 468, 485, 522

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,898,390 A	8/1975	Wells et al.	455/438
4,430,731 A	2/1984	Gimple et al.	
4,449,218 A	5/1984	Strehl	

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

EP	0 659 007 A2	6/1995
EP	0 659 007 A3	6/1995
EP	0 684 714 A2	12/1995
EP	0 740 451 A1	10/1996
WO	96/29814	9/1996

OTHER PUBLICATIONS

New Box Opens Doors For CLECs: Asher Waldfogel, Believed to have been published prior to Apr. 22, 1999.

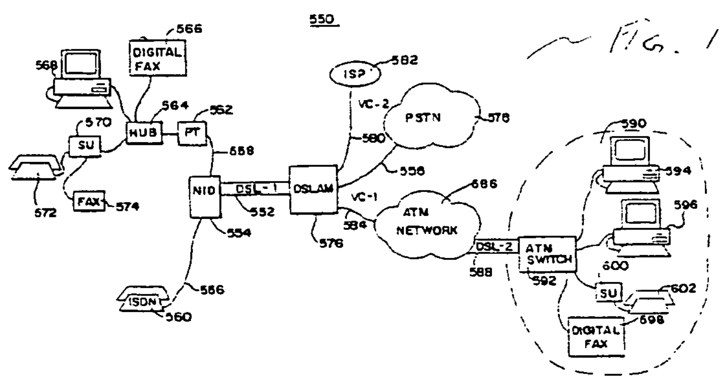
(List continued on next page.)

Primary Examiner—Hassan Kizou
Assistant Examiner—Saba Tsegaye
(74) *Attorney, Agent, or Firm*—Brinks Hofer Gilson & Lione

(57) **ABSTRACT**

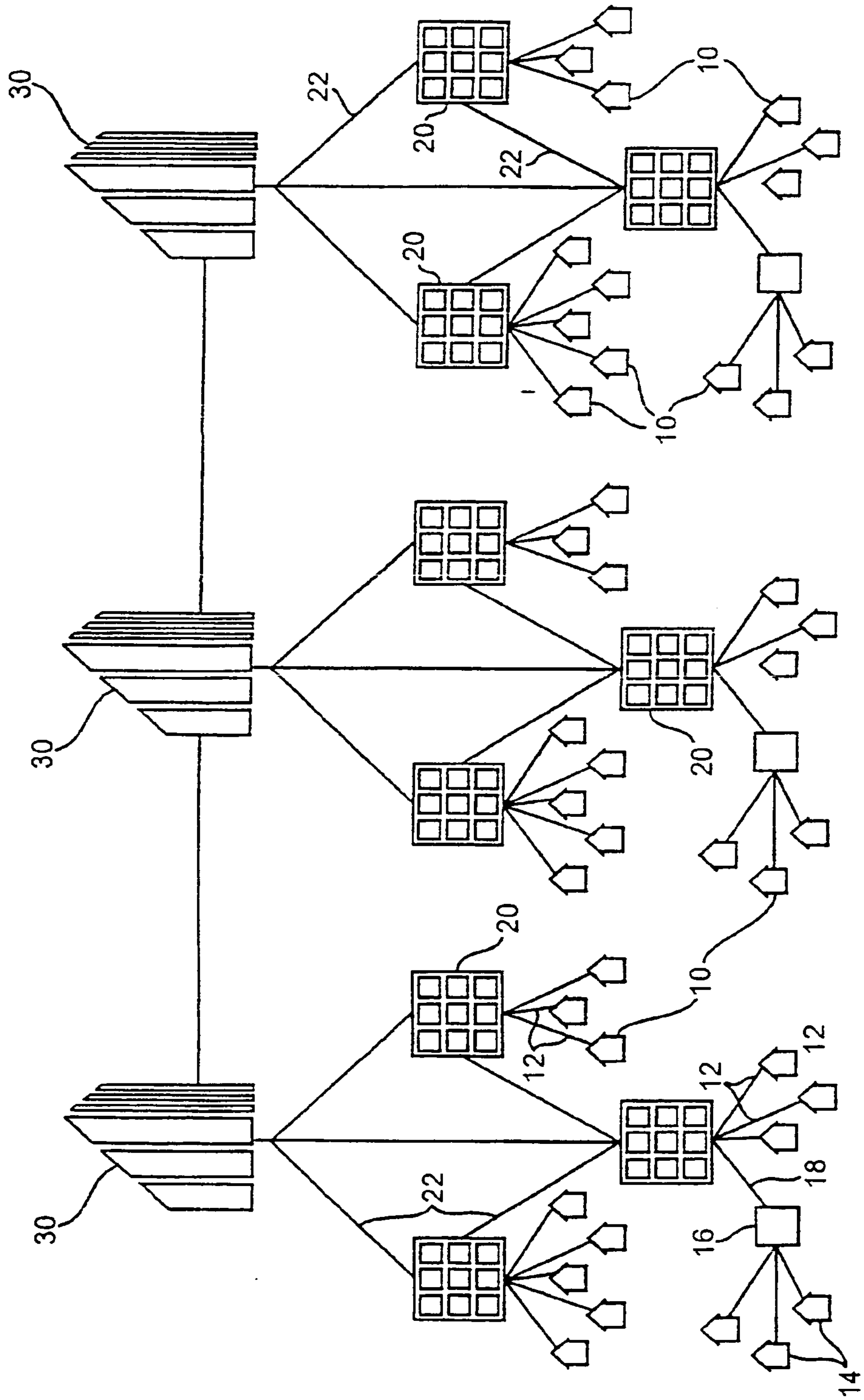
A wide area communications network (**500**) includes a first digital subscriber line (**502**). A first network interface device (**504**) connects to the digital subscriber line (**502**). The first network interface device (**504**) separates an ISDN channel (**508**) from a digital subscriber channel (**510**). An ISDN telephone (**508**) is connected to the network interface device (**504**). A protocol translator (**512**) is connected to the network interface device (**504**) by the digital subscriber channel (**510**). A hub (**514**) is connected to the protocol translator (**512**). A plurality of devices (**516, 518**) is connected to the hub (**514**). A digital subscriber line access multiplexer (**506**) is connected to the first digital subscriber line (**502**). The digital subscriber line access multiplexer (**506**) separates the digital subscriber channel from the ISDN channel (**522**). A public switched telephone network (**523**) is connected to the ISDN channel (**522**). An asynchronous transfer mode network (**526**) is connected to the DSLAM (**506**) by a first virtual circuit (**524**) of the digital subscriber channel. An ISP (**528**) is connected to the DSLAM (**506**) by a second virtual circuit (**530**) of the digital subscriber channel. A LAN 532 is connected to the ATM network (**526**) by the first virtual circuit (**524**).

11 Claims, 19 Drawing Sheets



~ FIG. 19

FIG. 1



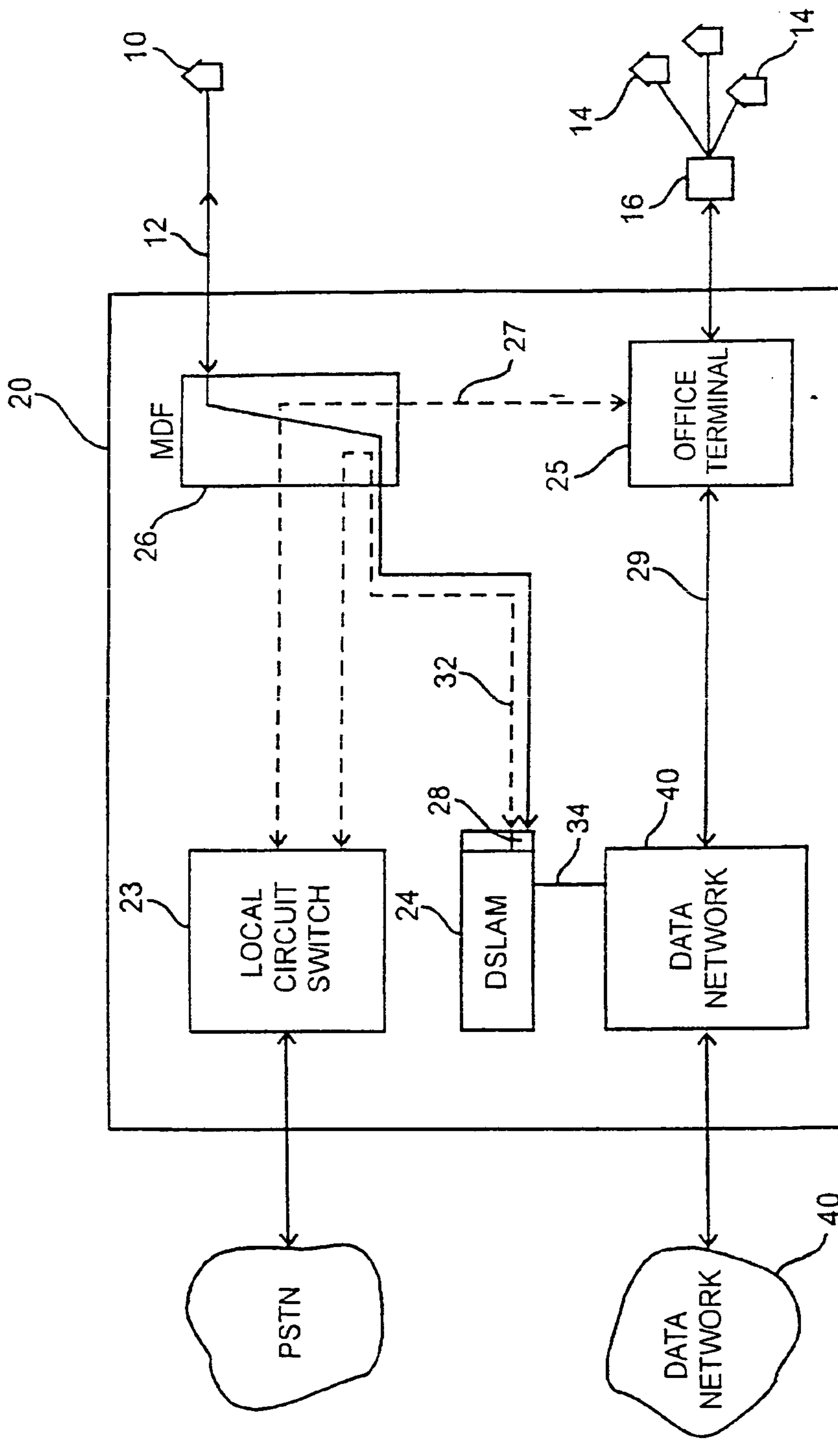
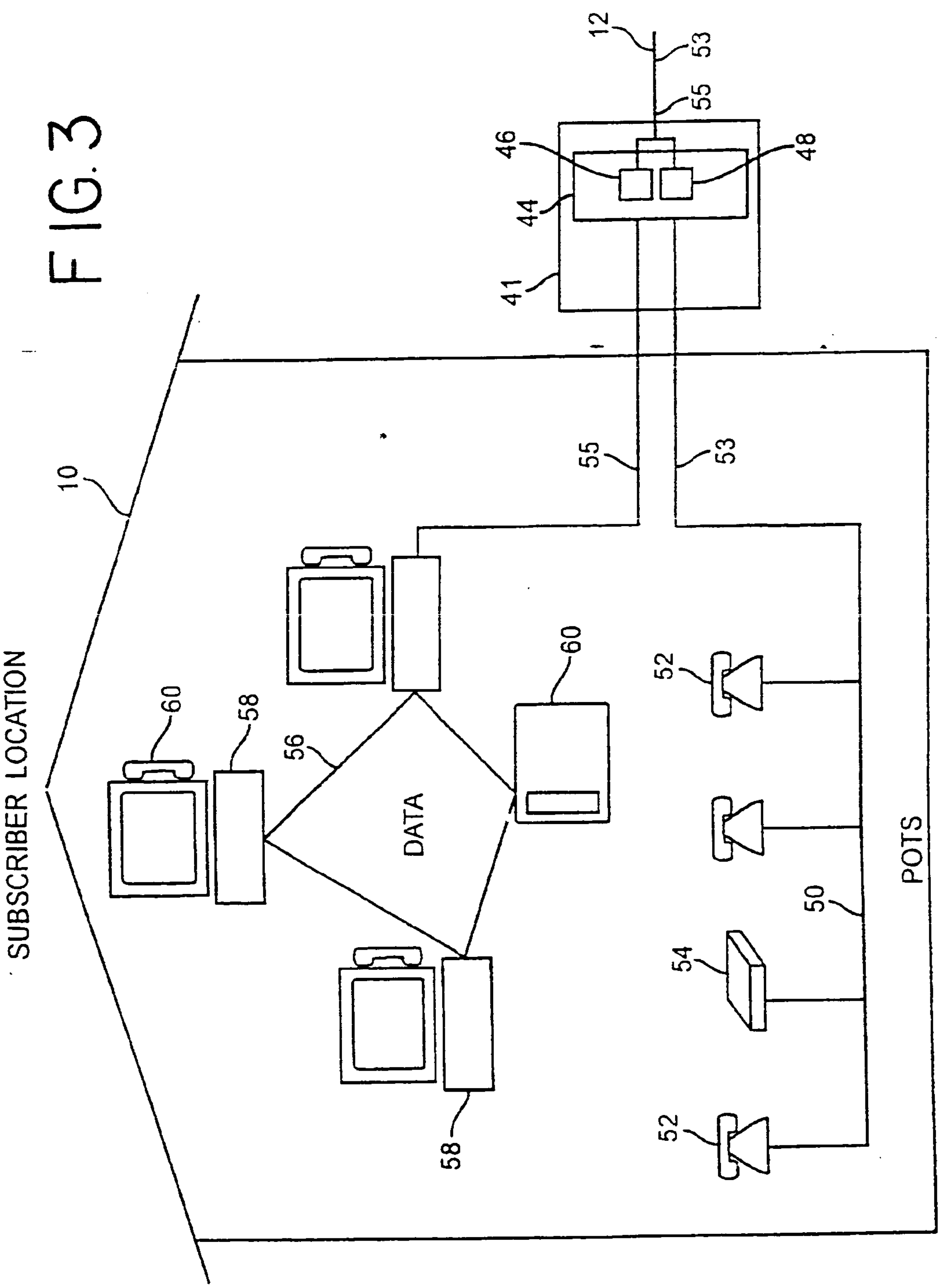

CENTRAL OFFICE
20
10
12
14
14
14
16
MDF
26
27
OFFICE TERMINAL
25
29
32
28
34
40
LOCAL CIRCUIT SWITCH
23
DSLAM
24
DATA NETWORK
PSTN
DATA NETWORK
40

FIG.2

FIG. 3


12
53
55
46
48
44
41
10
55
53
SUBSCRIBER LOCATION
60
58
56
DATA
60
52
POTS
50
54
52
58

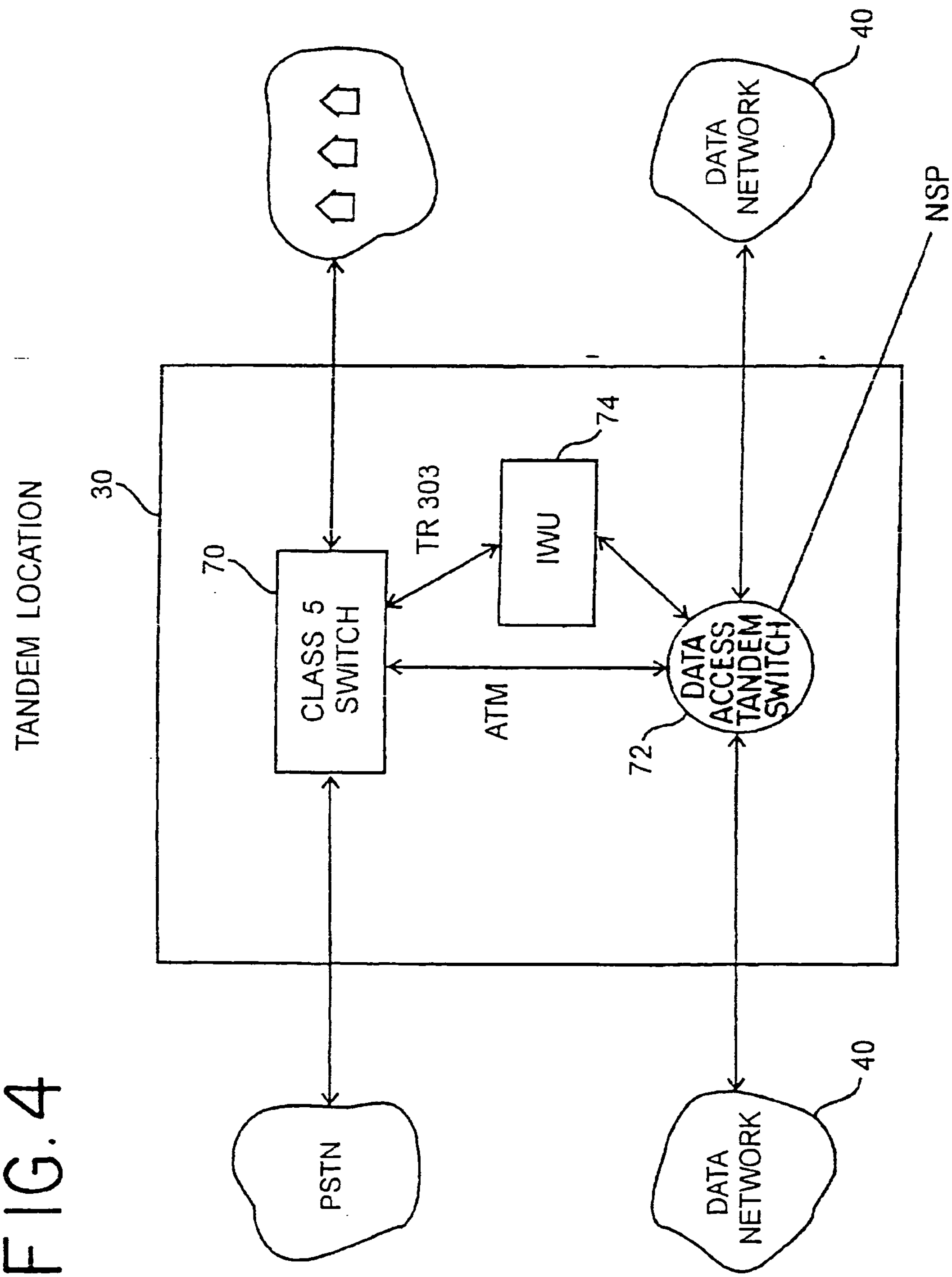

TANDEM LOCATION
30
70
CLASS 5 SWITCH
TR 303
IWU
74
ATM
DATA ACCESS TANDEM SWITCH
72
NSP
PSTN
DATA NETWORK
40
DATA NETWORK
40

FIG. 4

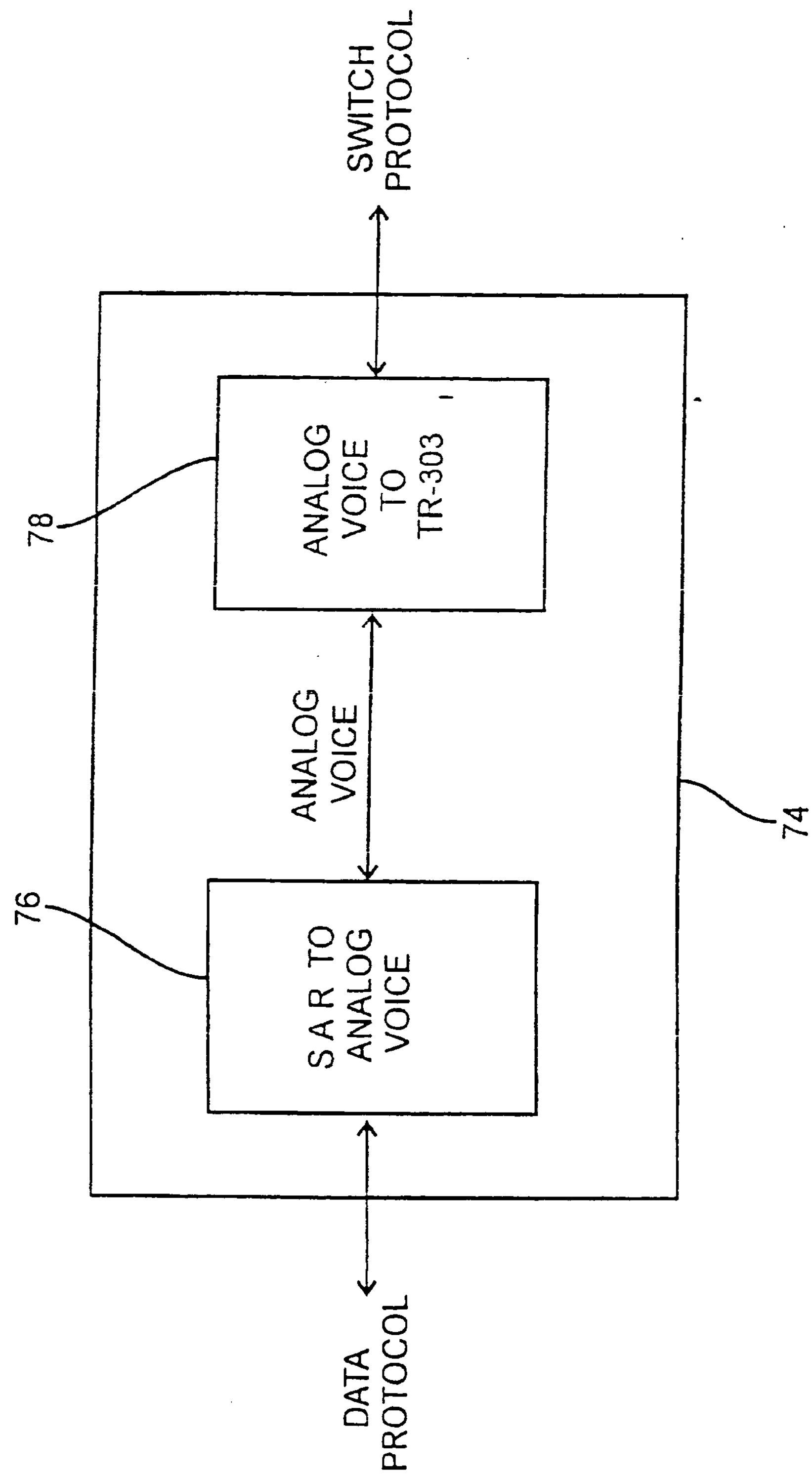
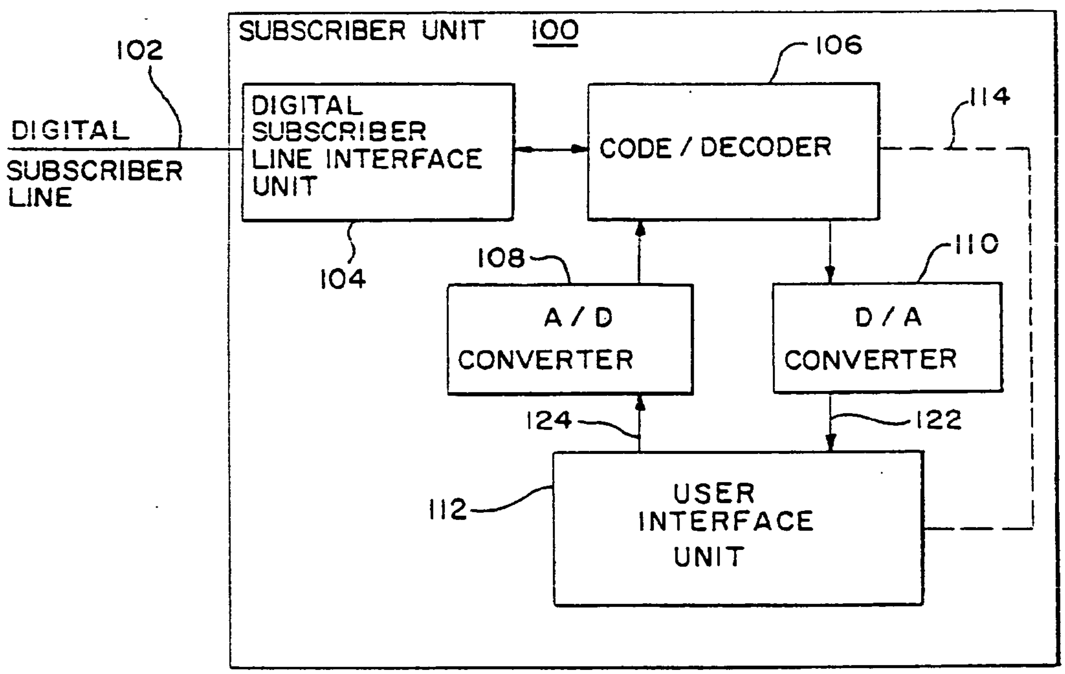

SWITCH PROTOCOL
ANALOG VOICE TO TR-303
78
ANALOG VOICE
74
76
S A R TO ANALOG VOICE
DATA PROTOCOL

FIG. 5

FIG. 6


SUBSCRIBER UNIT 100
102
DIGITAL SUBSCRIBER LINE
DIGITAL SUBSCRIBER LINE INTERFACE UNIT
104
106
CODE / DECODER
114
108
A / D CONVERTER
110
D / A CONVERTER
124
122
112
USER INTERFACE UNIT

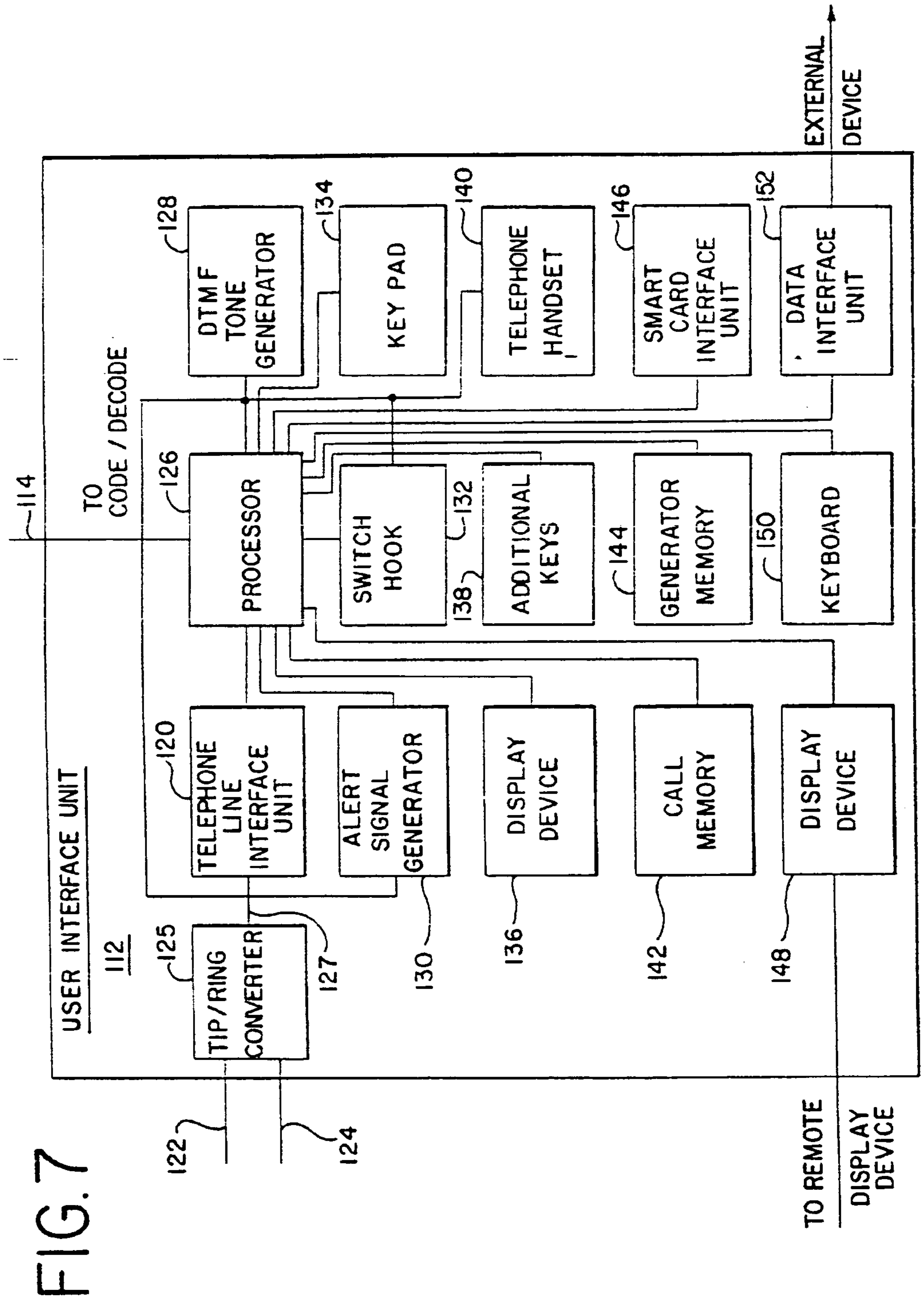

USER INTERFACE UNIT
112
TO CODE / DECODE
114
DTMF TONE GENERATOR
128
KEY PAD
134
TELEPHONE HANDSET
140
SMART CARD INTERFACE UNIT
146
DATA INTERFACE UNIT
152
EXTERNAL DEVICE
PROCESSOR
126
SWITCH HOOK
132
ADDITIONAL KEYS
138
GENERATOR MEMORY
144
KEYBOARD
150
TELEPHONE LINE INTERFACE UNIT
120
ALERT SIGNAL GENERATOR
130
DISPLAY DEVICE
136
CALL MEMORY
142
DISPLAY DEVICE
148
TIP/RING CONVERTER
125
127
122
124
TO REMOTE DISPLAY DEVICE

FIG.7

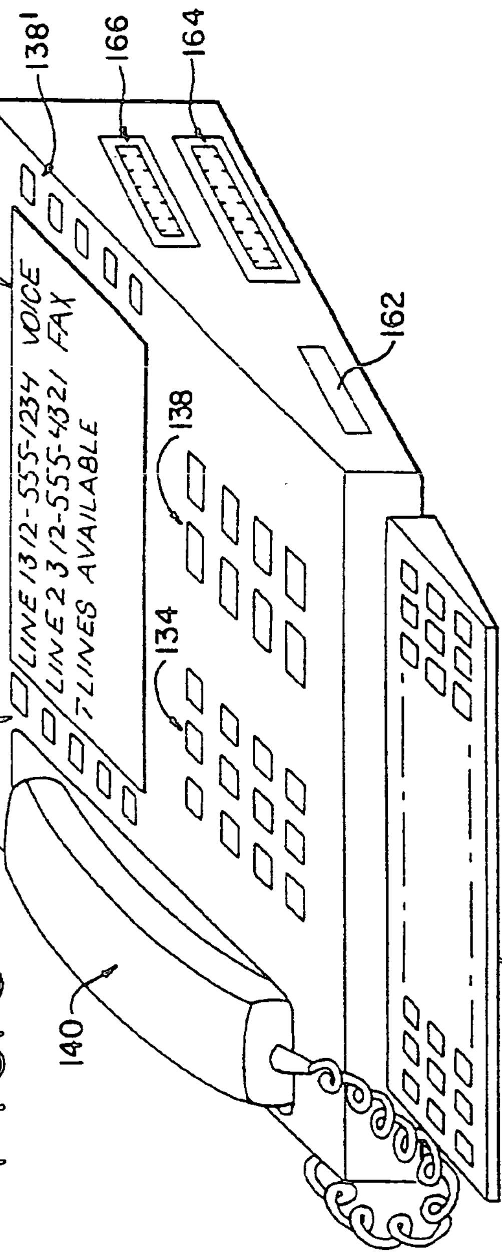

LINE 1 312-555-1234 VOICE
LINE 2 312-555-4321 FAX
7 LINES AVAILABLE

FIG. 8

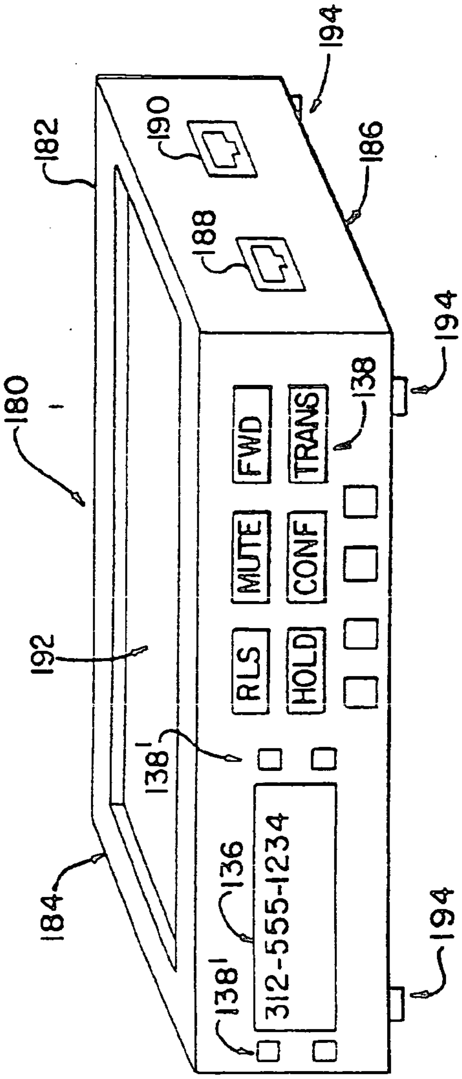

312-555-1234
RLS
MUTE
FWD
HOLD
CONF
TRANS

FIG. 9

FIG. 10

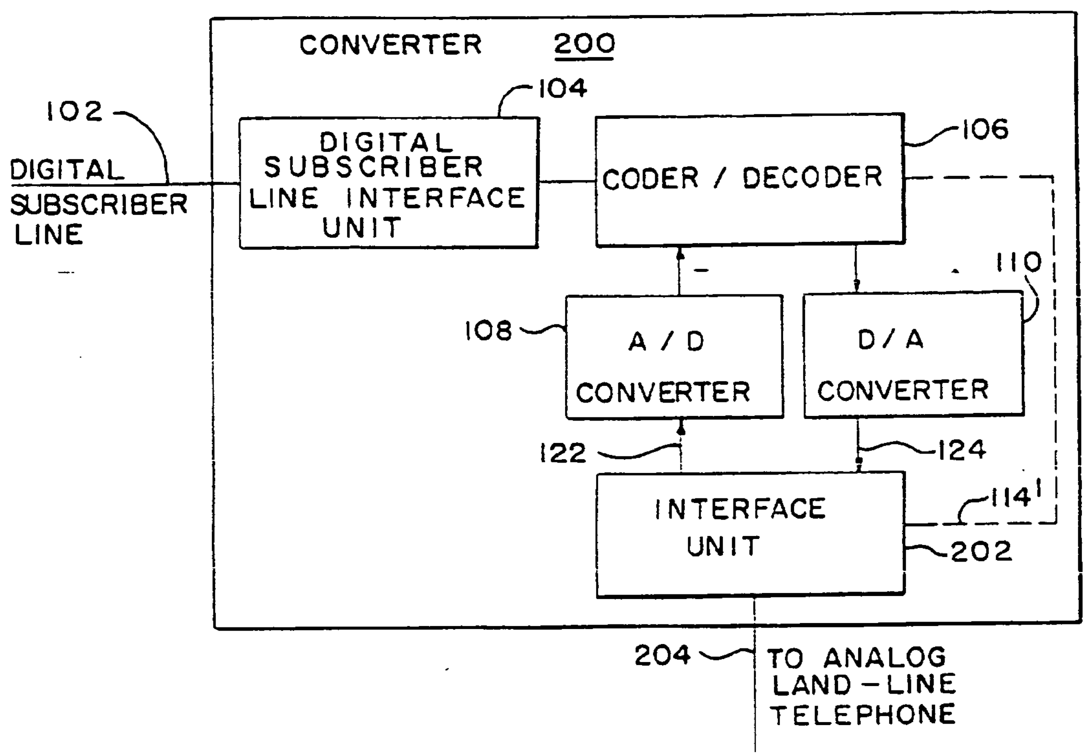
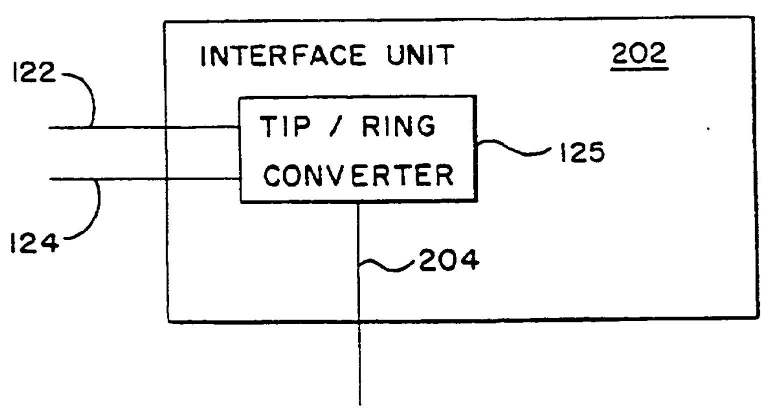

CONVERTER 200
104
102
106
DIGITAL SUBSCRIBER LINE
DIGITAL SUBSCRIBER LINE INTERFACE UNIT
CODER / DECODER
110
108
A / D CONVERTER
D / A CONVERTER
122
124
INTERFACE UNIT
114'
202
204
TO ANALOG LAND-LINE TELEPHONE

FIG. 11


INTERFACE UNIT 202
122
TIP / RING CONVERTER
125
124
204

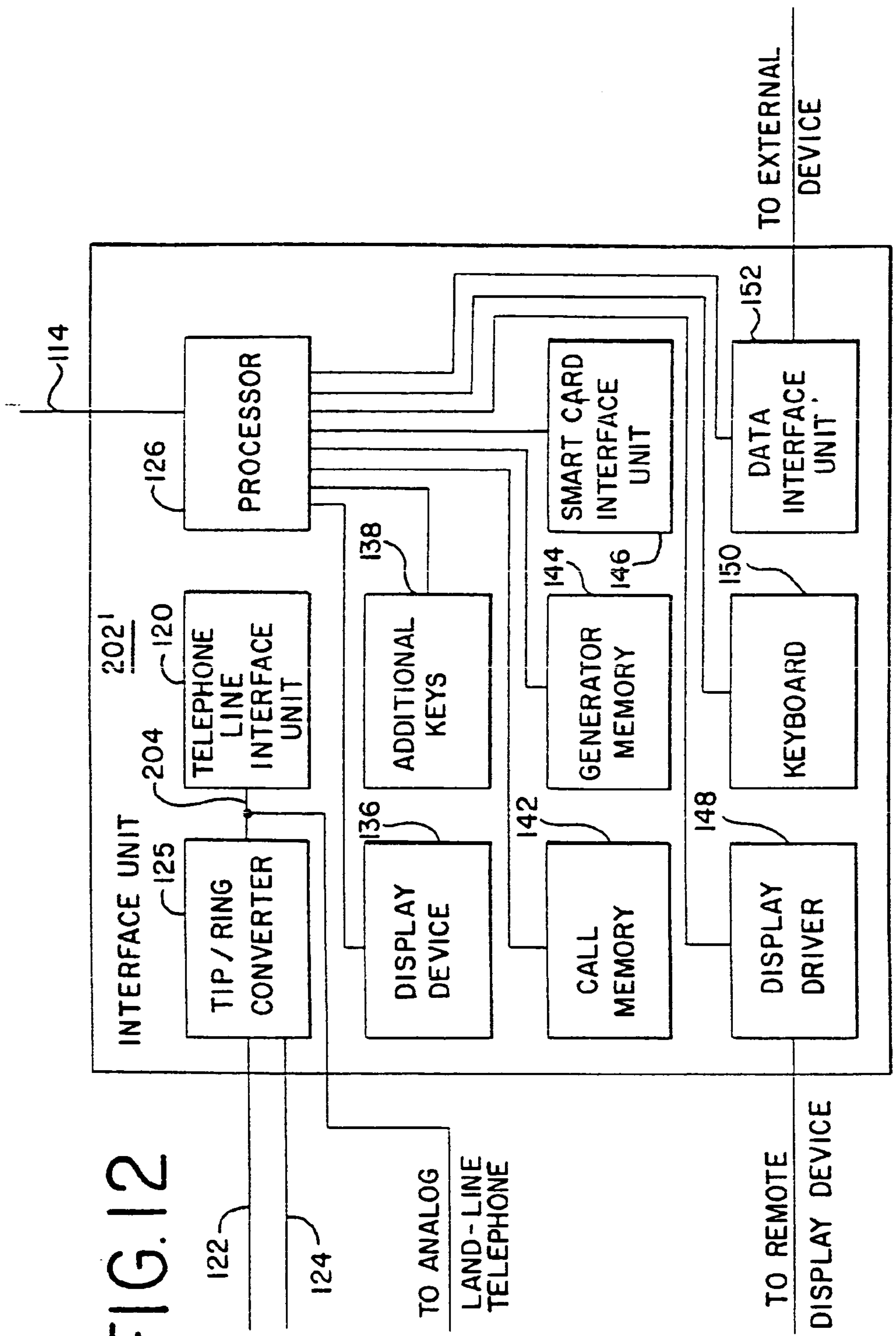

114
INTERFACE UNIT
202'
PROCESSOR
126
TELEPHONE LINE INTERFACE UNIT
120
204
TIP / RING CONVERTER
125
ADDITIONAL KEYS
138
DISPLAY DEVICE
136
SMART CARD INTERFACE UNIT
GENERATOR MEMORY
144
146
CALL MEMORY
142
DATA INTERFACE UNIT'
152
KEYBOARD
150
DISPLAY DRIVER
148
TO EXTERNAL DEVICE
122
124
TO ANALOG LAND-LINE TELEPHONE
TO REMOTE DISPLAY DEVICE

FIG.12

FIG. 13

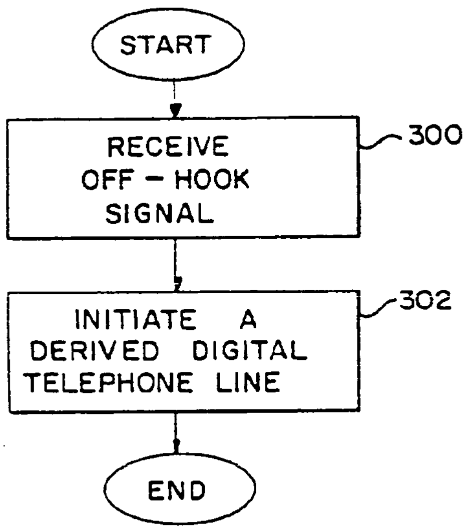

START
RECEIVE OFF - HOOK SIGNAL
300
INITIATE A DERIVED DIGITAL TELEPHONE LINE
302
END

FIG.14

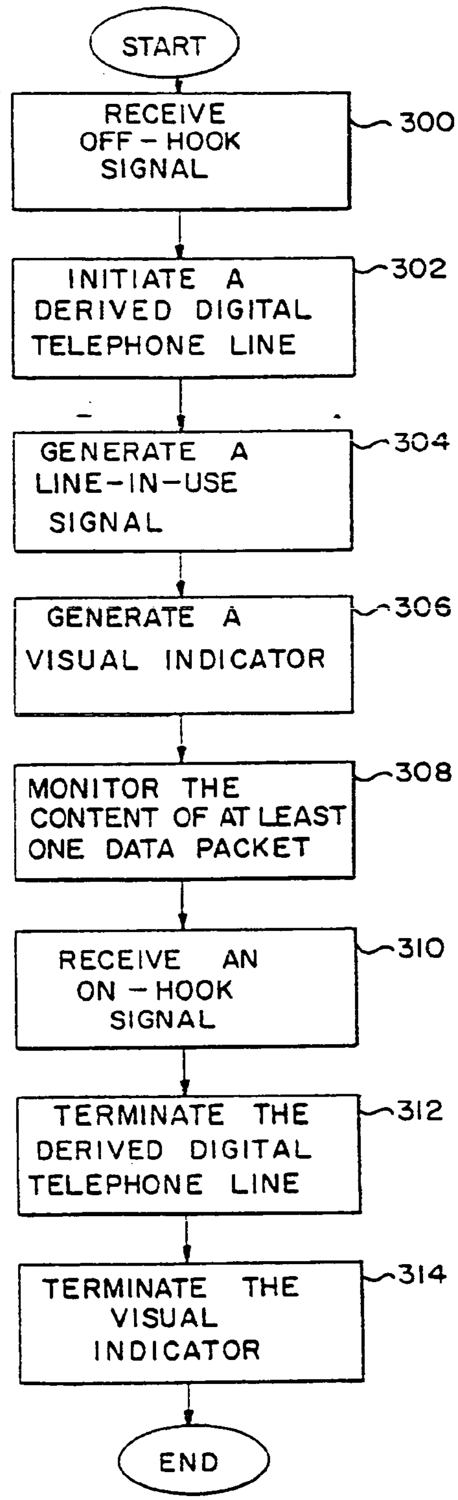

START
RECEIVE OFF - HOOK SIGNAL
300
INITIATE A DERIVED DIGITAL TELEPHONE LINE
302
GENERATE A LINE-IN-USE SIGNAL
304
GENERATE A VISUAL INDICATOR
306
MONITOR THE CONTENT OF AT LEAST ONE DATA PACKET
308
RECEIVE AN ON - HOOK SIGNAL
310
TERMINATE THE DERIVED DIGITAL TELEPHONE LINE
312
TERMINATE THE VISUAL INDICATOR
314
END

FIG. 15

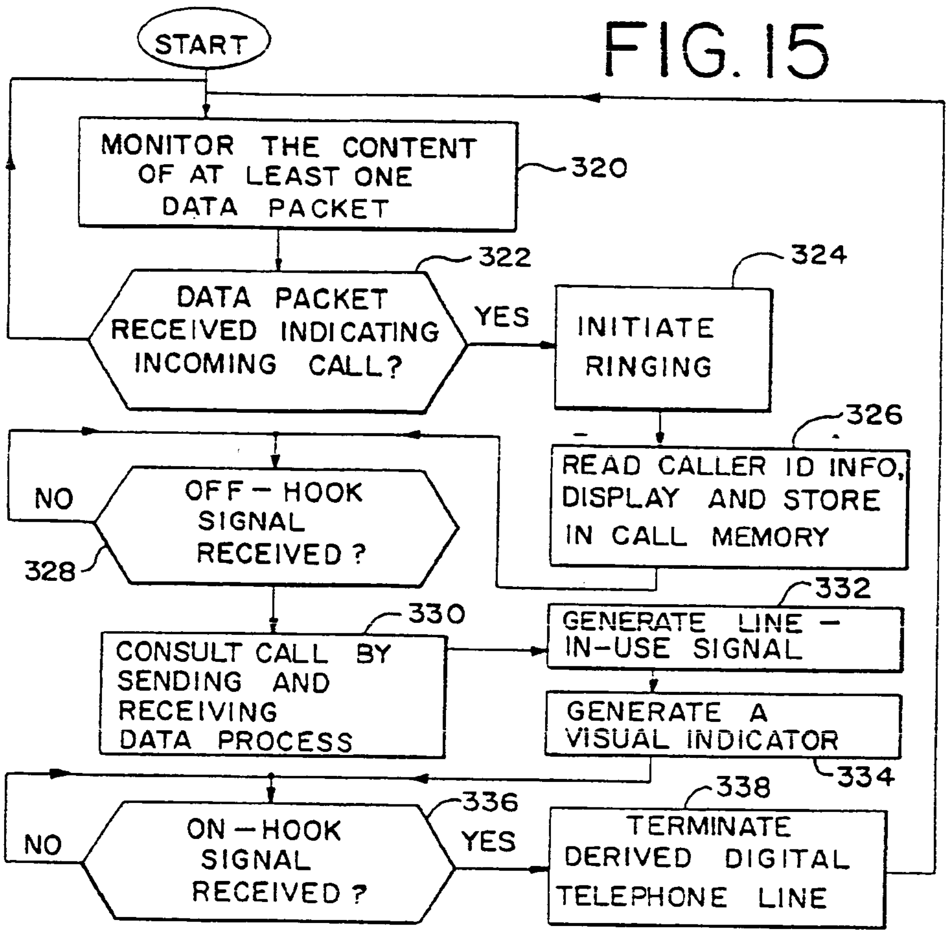

START
MONITOR THE CONTENT OF AT LEAST ONE DATA PACKET
320
DATA PACKET RECEIVED INDICATING INCOMING CALL?
322
YES
INITIATE RINGING
324
READ CALLER ID INFO, DISPLAY AND STORE IN CALL MEMORY
326
NO
OFF-HOOK SIGNAL RECEIVED ?
328
CONSULT CALL BY SENDING AND RECEIVING DATA PROCESS
330
GENERATE LINE-IN-USE SIGNAL
332
GENERATE A VISUAL INDICATOR
334
NO
ON-HOOK SIGNAL RECEIVED ?
336
YES
TERMINATE DERIVED DIGITAL TELEPHONE LINE
338

FIG. 16

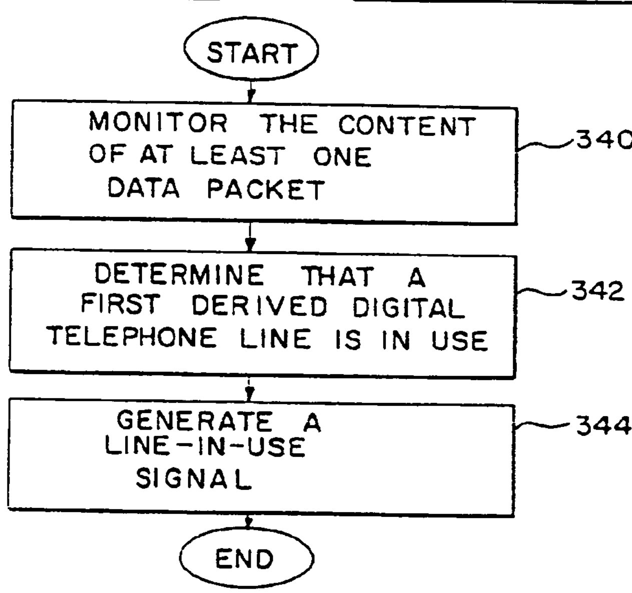

START
MONITOR THE CONTENT OF AT LEAST ONE DATA PACKET
340
DETERMINE THAT A FIRST DERIVED DIGITAL TELEPHONE LINE IS IN USE
342
GENERATE A LINE-IN-USE SIGNAL
344
END

FIG. 17

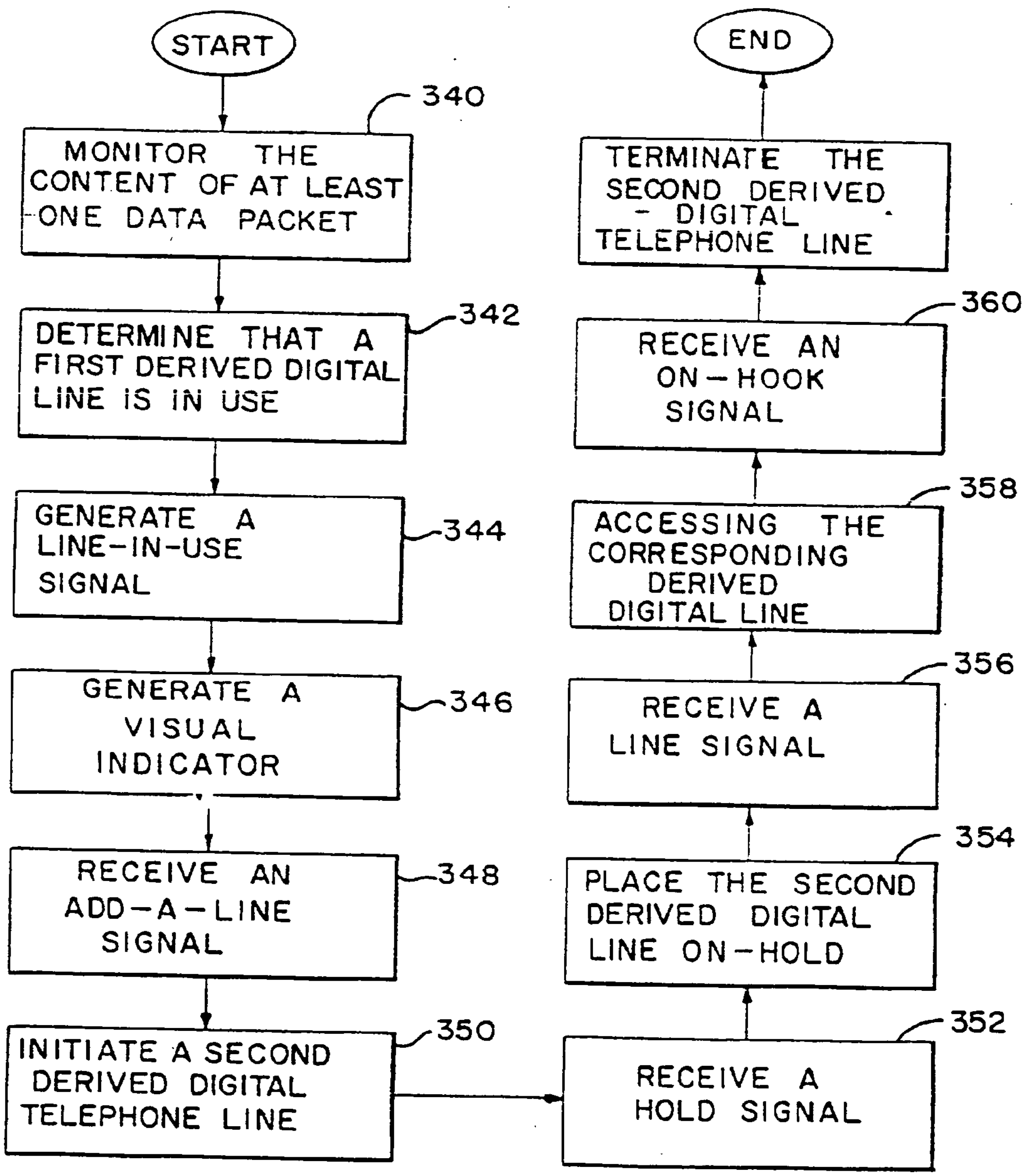
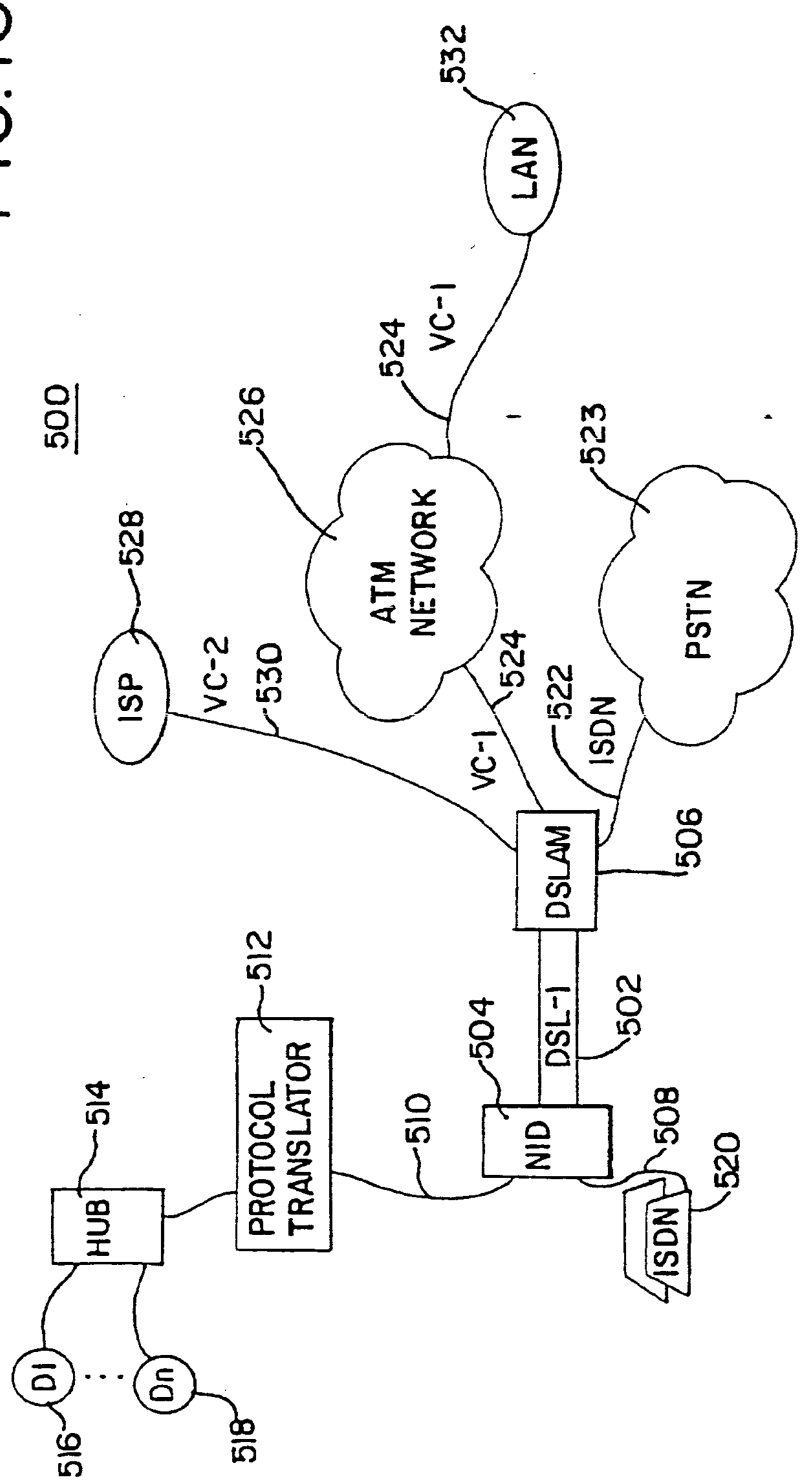

START
MONITOR THE CONTENT OF AT LEAST ONE DATA PACKET
340
DETERMINE THAT A FIRST DERIVED DIGITAL LINE IS IN USE
342
GENERATE A LINE-IN-USE SIGNAL
344
GENERATE A VISUAL INDICATOR
346
RECEIVE AN ADD-A-LINE SIGNAL
348
INITIATE A SECOND DERIVED DIGITAL TELEPHONE LINE
350
RECEIVE A HOLD SIGNAL
352
PLACE THE SECOND DERIVED DIGITAL LINE ON-HOLD
354
RECEIVE A LINE SIGNAL
356
ACCESSING THE CORRESPONDING DERIVED DIGITAL LINE
358
RECEIVE AN ON-HOOK SIGNAL
360
TERMINATE THE SECOND DERIVED DIGITAL TELEPHONE LINE
END

FIG.18


500
LAN
532
VC-1
524
ATM NETWORK
526
PSTN
523
ISP
528
VC-2
530
VC-1
524
522
ISDN
DSLAM
506
DSL-1
502
504
NID
510
508
ISDN
520
PROTOCOL TRANSLATOR
512
HUB
514
DI
Dn
516
518

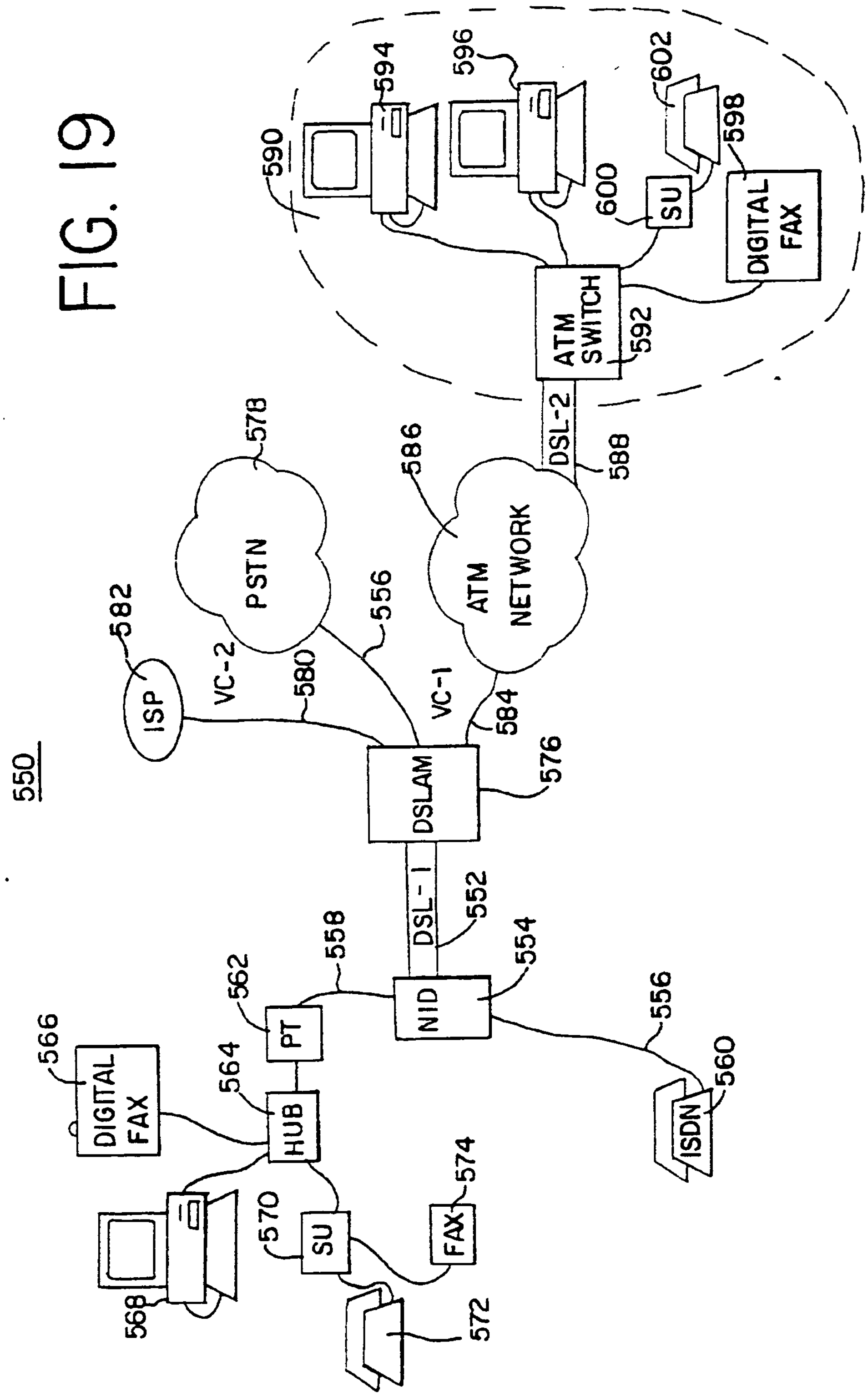

550
DIGITAL FAX
566
564
HUB
562
PT
558
NID
554
DSL-1
552
556
ISDN
560
568
SU
570
FAX
574
572
DSLAM
576
ISP
582
VC-2
580
556
PSTN
578
VC-1
584
ATM NETWORK
586
DSL-2
588
ATM SWITCH
592
590
594
596
SU
600
602
598
DIGITAL FAX

FIG. 19

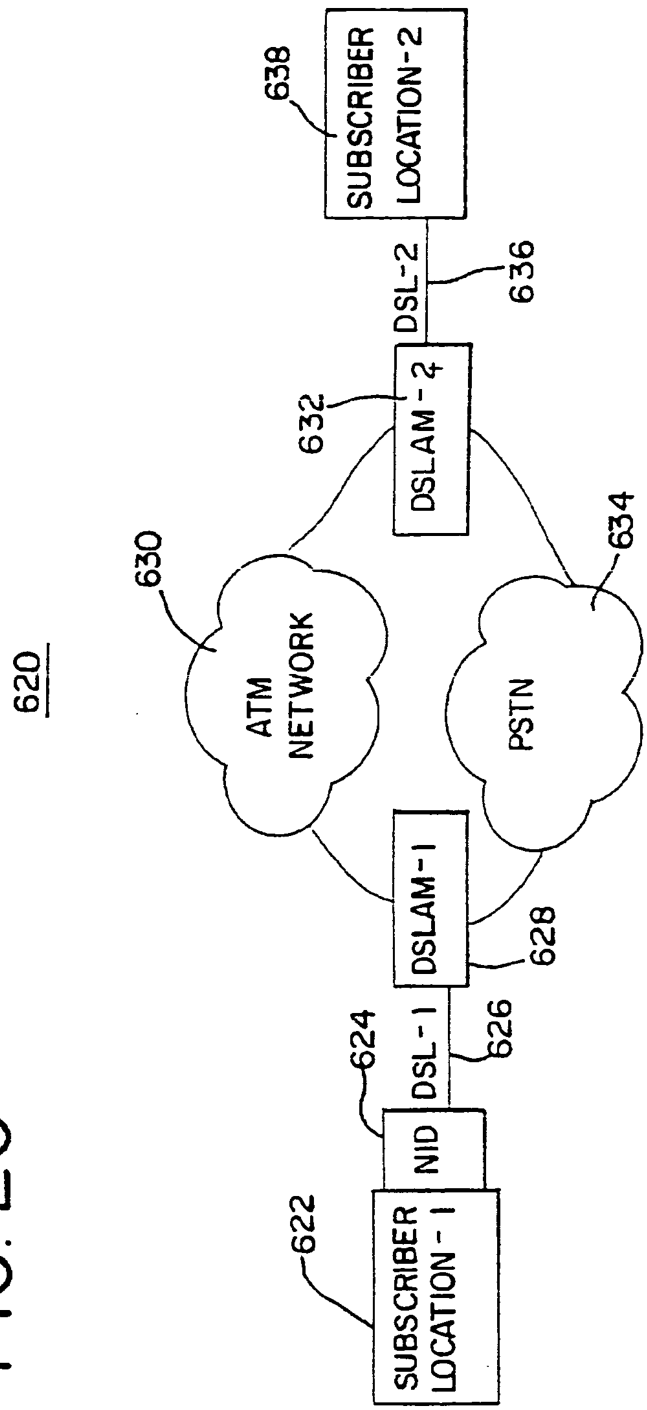

620
SUBSCRIBER LOCATION - 1
622
NID
624
DSL - 1
626
DSLAM - 1
628
ATM NETWORK
630
PSTN
634
DSLAM - 2
632
DSL-2
636
SUBSCRIBER LOCATION-2
638

FIG. 20

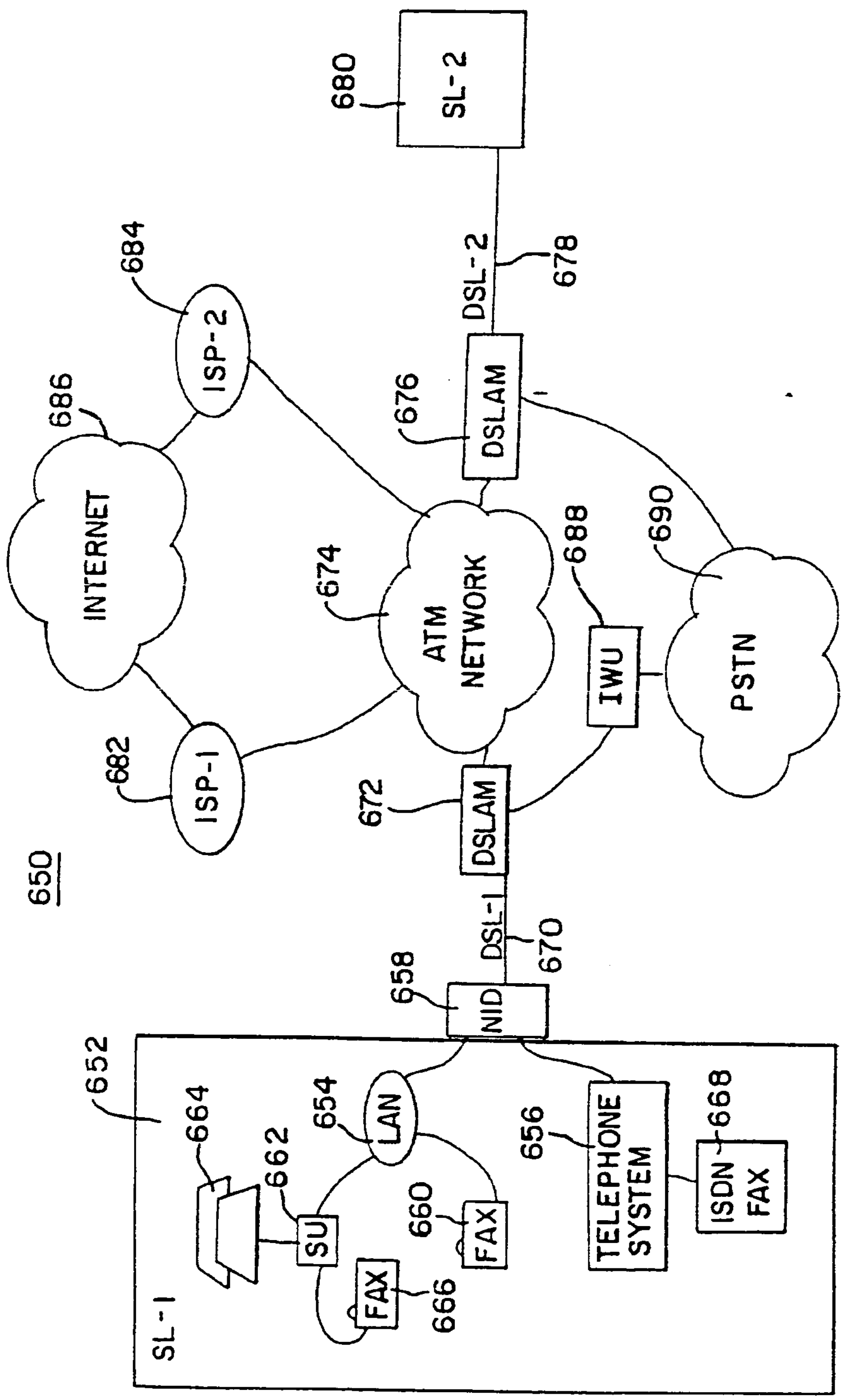

650
SL-2
680
DSL-2
678
ISP-2
684
INTERNET
686
DSLAM
676
ATM NETWORK
674
IWU
688
PSTN
690
ISP-1
682
DSLAM
672
DSL-1
670
NID
658
652
SL-1
LAN
654
SU
662
664
FAX
660
FAX
666
TELEPHONE SYSTEM
656
ISDN FAX
668

FIG.21

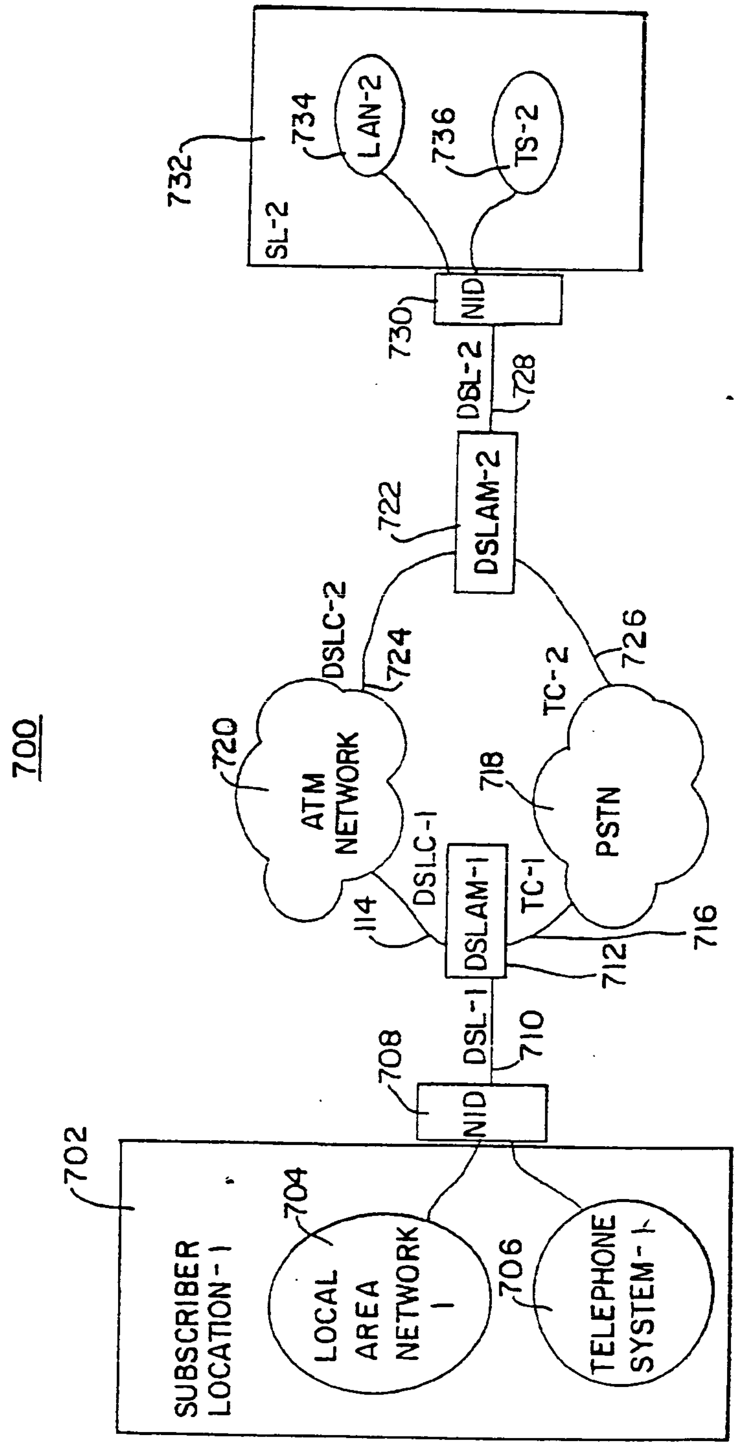

700
SUBSCRIBER LOCATION-1
702
LOCAL AREA NETWORK 1
704
TELEPHONE SYSTEM-1
706
NID
708
DSL-1
710
DSLAM-1
712
714
DSLC-1
TC-1
716
PSTN
718
ATM NETWORK
720
DSLC-2
724
TC-2
726
DSLAM-2
722
DSL-2
728
NID
730
SL-2
732
LAN-2
734
TS-2
736

FIG. 22

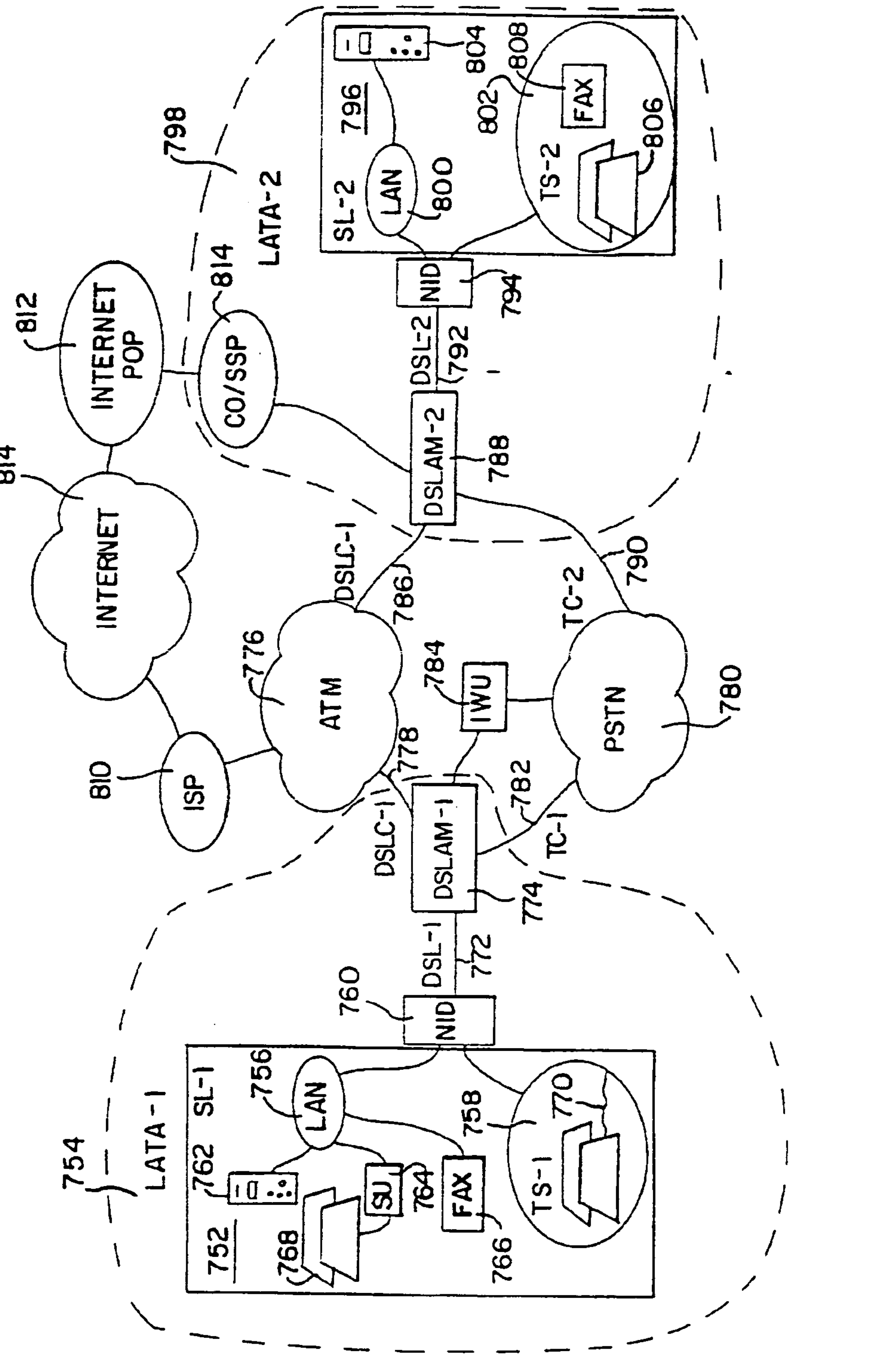

750
LATA-1
754
752
SL-1
LAN
756
762
SU
764
FAX
766
768
TS-1
758
770
NID
760
DSL-1
772
DSLAM-1
774
DSLC-1
778
TC-1
782
ATM
776
ISP
810
INTERNET
814
INTERNET
POP
812
CO/SSP
814
IWU
784
PSTN
780
TC-2
790
DSLC-1
786
DSLAM-2
788
DSL-2
792
NID
794
LATA-2
798
SL-2
796
LAN
800
804
802
808
FAX
TS-2
806

FIG. 23

WIDE AREA COMMUNICATION NETWORKING

CROSS-REFERENCE TO RELATED APPLICATIONS

The present invention is related to the following patent applications that are assigned to the same assignee as the present invention, the subject matter of which are incorporated herein by reference thereto:

1. "Method and Apparatus for Providing a Derived Digital Telephone Voice Channel," Ser. No. 08/742,164, filed on Nov. 1, 1996, now abandoned
2. "Home Gateway System Telephony Functions and Method," Ser. No. 09/061,833, Filed on Apr. 16, 1998.
3. "Telecommunication System, Method and Subscriber Unit for Use Therein," Ser. No. 09/119,094, filed on Jul. 20, 1998.
4. A00472
5. A00473.

TECHNICAL FIELD

The present invention relates to telecommunication systems, and more particularly to a wide area communication network.

BACKGROUND OF THE INVENTION

Present digital subscriber line (DSL) services are connected from a subscriber location to an internet service provider (ISP). DSL or ADSL (Asymmetric Digital Subscriber Line) provides a large bandwidth pipe that is ideal for communication networking. However, DSL uses the ATM (asynchronous transfer mode) protocol to transport the data over a twisted pair of copper wires. Typically, DSL is run over the local loop portion of the telephone network. ATM is a connection oriented service and most DSL lines are set up as a single permanent virtual circuit to an ISP. This single permanent virtual circuit does not allow other communication applications to use the DSL line. For instance, a user may want to share computer data over the DSL line without running over the internet. In addition, a user may want to use the DSL line for voice or facsimile data. None of these applications are allowed with present DSL services.

Thus there exists a need for a wide area communication network that can run over DSL lines.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is pointed out with particularity in the appended claims. However, other features of the invention will become apparent and the invention will be best understood by referring to the following detailed description in conjunction with the accompanying drawings in which:

FIG. 1 shows a schematic diagram of a telephone network in accordance with the present invention.

FIG. 2 shows a block diagram of the telco central office 20 of FIG. 1 in accordance with the present invention.

FIG. 3 shows a schematic diagram of a telephone subscriber location 10 such as a typical home or small office in accordance with the present invention.

FIG. 4 shows a block diagram of a tandem location in accordance with the present invention.

FIG. 5 presents a block diagram representation of an example interworking unit in accordance with the present invention.

FIG. 6 presents a block diagram of a subscriber unit in accordance with the present invention.

FIG. 7 presents a block diagram representation of a user interface unit in accordance the present invention.

FIG. 8 presents a perspective view of a subscriber unit in accordance with the present invention.

FIG. 9 presents a perspective view of a subscriber interface unit in accordance with the present invention.

FIG. 10 presents a block diagram representation of a converter in accordance with the present invention.

FIG. 11 presents a block diagram representation of an interface unit in accordance with the present invention.

FIG. 12 presents a block diagram representation of an interface unit in accordance with the present invention.

FIG. 13 presents a flowchart representation of a method in accordance with the present invention.

FIG. 14 presents a flowchart representation of a method in accordance with the present invention.

FIG. 15 presents a flowchart representation of a method in accordance with the present invention.

FIG. 16 presents a flowchart representation of a method in accordance with the present invention.

FIG. 17 presents a flowchart representation of a method in accordance with the present invention.

FIG. 18 presents a block diagram of a wide area communication network in accordance with the present invention.

FIG. 19 presents a block diagram of a wide area communication network in accordance with the present invention.

FIG. 20 presents a block diagram of a wide area communication network in accordance with the present invention.

FIG. 21 presents a block diagram of a wide area communication network in accordance with the present invention.

FIG. 22 presents a block diagram of a wide area communication network in accordance with the present invention.

FIG. 23 presents a block diagram of a wide area communication network in accordance with the present invention.

DETAILED DESCRIPTION OF THE PERFERRED EMBODIMENTS

The various embodiments of the present invention yield several advantages over the prior art. The embodiments described herein allow a small business to setup a wide area communication network. This allows small businesses to transmit voice, data, facsimile, video and other data over a wide area communication network having DSL lines. Note that FIGS. 1–17 describe a variety of background information about digital subscriber lines and a method of deriving a telephone line. FIGS. 18–23 show embodiments of a wide area communication network.

FIG. 1 shows a schematic diagram of a telephone network in accordance with the present invention. Telephone subscribers 10 are typically serviced by analog telephone lines carried to the central office 20 by a subscriber loop 12 including twisted pairs of copper wires. A number of subscribers 14 may also be connected by subscriber loops to a remote terminal 16 which combines a number of subscribers 14 onto a digital multiplexed data line 18 for transmission to the central office 20. For example, a 24 channel multiplexed T1 line is commonly used in North America for the data line 18.

Typically, a number of central offices 20 are connected by direct trunk circuits 22 or through tandem locations 30. The tandem locations 30 provide trunk circuits 22 to connect two

central offices or other tandem locations 30. The tandem locations 30 can thus provide connections between central offices which do not have direct interconnecting trunks. It is to be understood that telephone switching networks may have multiple levels of tandem switching or other network topologies. The unique features of the present invention will be identified with respect to the features of the components of the network and their unique configuration.

FIG. 2 shows a block diagram of the telco central office 20 of FIG. 1 in accordance with the present invention. The central office 20 preferably includes a means to provide analog telephone lines such as conventional POTS. Conventional POTS is typically handled by the local telephone switching device 23. Local telephone switching devices such as a Northern Telecom DMS-100 or Lucent No. 5 ESS are well known to those skilled in the art. In alternative embodiments, an analog telephone line may also be provided by a Centrex type service or private branch exchange (PBX). As known to those skilled in the art, an analog telephone service may also be provided by a digital carrier system such as a T1 carrier or other type of concentrator.

In addition to POTS service, the central office may also include a means to provide a digital data line. For example, a digital data line may be implemented by a digital subscriber line access multiplexer (DSLAM) 24 to multiplex traffic from digital subscriber loops. Digital subscriber loops or digital carrier systems provided by remote terminal 16 and office terminal 25 provide digital data lines which enable subscribers 10 (FIG. 1) to transmit large amounts of digital multiplexed data traffic over the POTS twisted pair telephone line. The digital subscriber loop is preferably an Asymmetric Digital Subscriber Line (ADSL). ADSL typically implements a digital subscriber line with a maximum data rate from the central office 20 to the subscriber 10 which is higher than the maximum available data rate from the subscriber 10 to the central office 20. For example, ADSL typically provides an asymmetric data rate of 1.5 megabits-per-second (mbs) to the subscriber from the central office and about 400 kilobits-per-second (kbs) from the subscriber location to the central office. Most preferably, ADSL implements an ATM data transmission protocol between the subscriber 10 (FIG. 1) and the central office 20. Of course, other types of data transmission protocols may be utilized. In alternate embodiments, the digital data line may be provided by other types of digital carrier systems such as a SONET ((Synchronous Optical Network) based digital systems.

As shown in FIG. 2, the subscriber loop pairs 12 carrying both analog voice and digital data traffic from subscribers 10 to the central office 20 are terminated at a main distribution frame (MDF) 26. From the MDF 26, the subscriber loops 12 are connected to a means for separating POTS voice 32 frequencies from digital data traffic 34 such as a splitter 28, for example. Preferably, the splitter 28 is implemented by the DSLAM 24. The internal operation of the splitter 28 will be described later in more detail in connection with a splitter at the subscriber 10.

The splitter 28 preferably has two outputs: one for POTS signals and another for data traffic. From the splitter 28, the separated POTS voice signals 32 are connected back to the MDF 26 and onto the local switching device 23 handling POTS telephone calls. The data traffic output of the splitter 28 is directed to the DSLAM 24 to multiplex the digital data into a format suitable for transport on a data network 40. Preferably, the DSLAM 24 multiplexes and packages a number of lower signal rate digital data lines to a SONET OC-3 or a DS-1 rate signal which is carried by a fiber optic network. Depending on the data network 40, the DSLAM 24 may operate at higher bit rates such as those appropriate for SONET OC-12. It should be understood that the data network 40 may be of many different topologies. Preferably, the data network 40 is connected to a tandem location 30 to allow access to other central offices.

In the case of subscriber loops that are connected to the central office through a digital loop carrier system (i.e., a remote terminal 16 and an office terminal 25), the DSLAM 24 and its splitter 28 are preferably placed at the remote terminal 16. The data and voice signals are separated with the splitter 28, as described above. The voice signals are carried on the digital loop carrier system to the office terminal 25 where they are connected through the MDF 26 to the local circuit switch 23. Preferably, the data signals are carried on a separate optical fiber or SONET frame in the carrier system so that they can easily be separated from the voice signals in the office terminal 25. These signals are transmitted from the office terminal to the data network 40.

FIG. 3 shows a schematic diagram of a telephone subscriber location 10 such as a typical home or small office in accordance with the present invention. A network interface device (NID) 41 connects the subscriber to the public switched telephone network (PSTN). The subscriber loop 12 between the subscriber 10 and the central office 20 is terminated at the NID 41. Customer premise equipment (CPE) such as a standard telephone set 52 or other CPE equipment such as a key system, PBX, or computer network 56 to access the PSTN is connected at the NID 41. Voice signals from an analog telephone line 53 and data signals from a digital data line 55 are typically carried to the subscriber 10 on the same subscriber pair 12.

In the preferred embodiment of the invention, the NID 41 includes a means for separating voice frequency signals from data signals. Preferably, a splitter 44 separates voice frequency signals from the data traffic sharing the subscriber loop 12 wire pair. For example, to separate POTS from data traffic, the splitter 44 typically includes a high-pass filter 46 and a low-pass filter 48. To separate POTS voice signals, the low-pass filter 48 blocks high frequency signals, for example signals above 5 KHZ, passing only lower voice frequency signals on a conventional CPE POTS loop 50. The voice signals on the CPE POTS loop 50 are connected to standard telephone 52 such as a Bell 500 set providing conventional POTS service. It should be noted that a conventional computer modem 54 can also utilize the conventional CPE POTS loop 50.

To recover data traffic, the high-pass filter 46 blocks low frequency signals, for example signals below 5 KHz, leaving only high frequency data traffic signals to be sent out on a separate CPE data network loop 56. The CPE data network loop 56 is connected to CPE equipped to access data traffic, for example, a network of personal computers. In the preferred embodiment, the CPE data network 56 implements an asynchronous transfer mode network (ATM). Each of the personal computers 58 is equipped with a ATM network interface card (NIC) to allow the computer to access the CPE data network 56. The NIC 41 preferably also includes data segmentation and reassembly (SAR) capability to packetize data for transmission on the data network 56. Of course, other types of computer networks, such as an Ethernet network, may also be implemented.

Preferably, the CPE data network 56 is also equipped with one or more digital telephones 60 capable of interfacing the data network 56 to allow a subscriber to place a voice telephone call over the CPE data network 56. For example,

a digital telephone 60 may be implemented with one of the personal computers 58 on the data network 56 by adding a telephone handset and an appropriate NIC with telephony functions. The telephone handset transmits and receives analog voice signals similar to a conventional handset. The computer/NIC provides SAR capability for converting analog voice to a digital packet stream for transmission over the CPE data network 56. The data network 56 also carries the basic telephony signaling functions. One such system capable of providing such a digital telephone is an ATM network based telephone system from Sphere Communications in Lake Bluff, Ill.

Using the CPE data network 56, the subscriber 10 can place a voice call using a telephone line derived from the digital data line. POTS service operates as a usual over the POTS wiring 50 to provide regular telephone service such as a telephone line carrying analog voice signals. In addition, the data network 56 with digital telephone 60 also has the capability to place voice telephone calls using one or more derived voice lines implemented through the data network, as will be explained below in more detail.

FIG. 4 shows a block diagram of a tandem location in accordance with the present invention. The Class 5 local switch 70 typically connects local subscriber loops to the telephone network, while a separate tandem voice switch (not shown) provides conventional circuit-switched connections for directing POTS traffic between central offices 20 (FIG. 1) of the PSTN. Class 5 local switches such as the Lucent 5 ESS and the Nortel DMS 100, and tandem voice switches such as the Lucent 4ESS and the Nortel DMS 250 are known to those skilled in the art. In comparison, the means for providing data access to data networks is preferably a packet switch handling digital data traffic. For example, a data access tandem switch 72 provides access to data networks carrying digital data traffic. Preferably, the data networks are equipped to accept ATM packet-switched connections. The data access tandem switch 72 is an ATM fabric switch configured to provide virtual connections on demand between end users and providers of data networks and services. The data access tandem switch 72 may connect end users to various network service providers (NSPs) such as UUNet, MCI, Sprintnet, and AADS (Ameritch Advanced Data Services).

The tandem location 30 may also include a means to interface the data access tandem 72 and the Class 5 switch. For example, an interworking unit (IWU) 74 may implement an interface between the data access tandem switch 72 and the Class 5 switch 70 of the PSTN. The IWU 74 enables voice telephone calls carried by the data network 40 to access the PSTN through the Class 5 switch 70. The IWU 74 is capable of converting a voice telephone call in the data network protocol from the data access tandem switch 72 into the circuit-switch protocol of the Class 5 switch 70. Preferably, the IWU 74 interfaces an ATM packet data stream to a multiplexed circuit-switch protocol with dynamic allocation of voice channels such as TR-303.

FIG. 5 presents a block diagram representation of an example interworking unit in accordance with the present invention. In particular, the IWU 74 performs the SAR 76 of voice data from an ATM stream into a analog voice signal. The analog voice signal is then converted 78 into the data protocol such as a TR-303 protocol. More preferably, as seen in FIG. 4, the IWU 74 converts the packetized ATM voice streams to a digital PCM format which is then converted to the desired TR-303 protocol. It should be noted that the local switch 70 may also be directly connected to a data access tandem 72 without the IWU interface 74. Newer generation digital switches may be capable of directly interfacing with the data transfer protocol of the data access tandem 72. For example, new generation circuit-switches may directly accept an ATM data stream for switching into the PSTN without the need for an IWU.

While a TR-303 protocol is described above, other protocols may likewise be used in accordance with the present invention. In particular, other protocols including a PRI protocol, TR-08 protocol or a TR-57 protocol could likewise be used within the scope of the present invention.

With the system of FIGS. 1-5, a derived voice telephone line using the data network can be implemented and utilized in conjunction with the methods and systems that follow.

A caller places a digital voice call similar to an ordinary telephone call using the digital telephone 60 of FIG. 3. The SAR and A/D function of the digital telephone 60 converts the caller's analog voice signals to a packetized digital data stream for transport over the subscriber data network 56. Preferably, the packetized data stream is in an ATM format.

The subscriber data network 56 carries the derived telephone line data stream to the high frequency portion 55 of the DSL devoted to digital communications. Next the high frequency portion 55 of the DSL is combined with the low frequency portion 53 of the DSL on the subscriber loop 12 where it is transported to the central office 20. Note, the derived telephone line uses the digital data portion 55 of the subscriber data network 56, leaving the lower frequency portion (POTS telephone signal) available for analog telephone voice calls.

At the central office 20 shown in FIG. 2, the splitter 28 separates the derived telephone line data stream from POTS traffic. The derived telephone line data stream is multiplexed by the DSLAM 24 together with a number of data streams or derived telephone line data streams from other subscribers. For example, the DSLAM 24 may combine data streams from a number of different subscribers into a higher rate digital signal such as a DS-3 or OC-3 signal. The telephone line data stream is then carried by the OC-3 signal over the data network 40 to the tandem location 30.

At the tandem location 30 shown in FIG. 4, the derived telephone line and data sessions are switched by the data access tandem 72. Preferably, data sessions to a NSP are directly switched by the data access tandem 72 to the desired NSP without entering the PSTN. For voice calls which must enter the PSTN, the data access tandem 72 directs the derived telephone line data streams to the IWU 74.

The IWU 74 preferably converts the derived telephone line data stream to a voice signal in a TR-303 format which can be switched by the Class 5 telephone switch 70. Through the Class 5 switch 70, the derived voice call enters the PSTN and is switched as a POTS call. If needed, a separate tandem switch establishes a circuit connection to the desired central office 20.

FIG. 6 presents a block diagram of a subscriber unit in accordance with the present invention. In particular, a subscriber unit 100 allows connection with a public switched telephone network. The public switched telephone network has at least one switch and at least one digital subscriber line 102, such as described in FIGS. 1-5, in communication with the switch. In accordance with the present invention, the subscriber unit 100 is operable to send and receive voice calls over the public switched telephone network.

While the various embodiments of the present invention have been described in conjunction with a public switched telephone network, these embodiments could similarly apply to voice communications over other communication

networks. In particular, telephone calls, within the scope of the present invention, can be transmitted using a data communications network such as the Internet as a transport medium for a least a portion of a call. In these embodiments of the present invention the functionality of an analog local switch or digital switch could be performed by a server and router corresponding to a local Internet service provider or could include an IP (Internet Protocol) gateway in combination with a central office switch. Further the switch of the present invention could be a central office circuit switch or a packet switch depending on the nature of the network.

The subscriber unit **100** includes a digital subscriber line interface unit **104** receives the plurality of data packets from the digital subscriber line **102** and identifies selected ones of the plurality of received data packets corresponding to a received data stream of a first derived digital telephone. The subscriber unit **100** is further operable to transmit, on the digital subscriber line, a plurality of transmitted data packets corresponding to a transmitted data stream of the first derived digital telephone line.

In one embodiment of the present invention data packets are formatted in accordance with the Asynchronous Transfer Mode (ATM) protocol. Further, a hierarchical protocol structure could likewise be used encompassing, for instance, an Ethernet protocol carried by ATM or an internet protocol (IP) such as TCP/IP carried by ATM. However, other packet data protocols and hierarchical structures and combinations could likewise be implemented within the scope of the present invention.

Packets received by the subscriber unit **100**, destined for receipt by subscriber unit **100** include an address, consistent with the particular protocol or protocols used for formatting the data packets, that corresponds to either the subscriber unit **100** or to a corresponding subscriber. In accordance with an embodiment of the present invention whereby an IP is used, data packets directed to the subscriber unit **100** could be identified based on a particular IP node address or URL corresponding to either the particular subscriber unit **100** or to a particular subscriber using subscriber unit **100**. Alternatively, an ATM address could be used for the same purpose in an ATM protocol environment.

The subscriber unit **100** further includes a coder/decoder **106**. The coder/decoder **106** receives the transmitted data stream from analog-to-digital (A/D) converter **108** and codes the transmitted data stream into the plurality of transmitted data packets. The coder/decoder **106** also receives the plurality of received data packets from the digital subscriber line interface unit **104** and decodes the plurality of received data packets into a received data stream to be transmitted to the digital-to-analog (D/A) converter **110** on line **122**.

Analog-to-digital converter **108** converts a transmitted analog signal from user interface unit **112** into the transmitted data stream. Digital-to-analog converter **110** converts the received data stream into a received analog signal for transmission to the user interface unit **112** on line **124**.

In this fashion, digital subscriber line interface unit **104**, coder/decoder **106**, A/D converter **108** and D/A converter **110** operate in concert to send and receive basic telephony signaling between the digital subscriber line **102** and an user interface unit **112**. This user interface unit **112** provides the basic functionality of a standard analog telephone set. In particular, the user interface unit **112** provides an interface to a user of the subscriber unit and, at a minimum, generates the transmitted analog signal sent to A/D converter **108** and generates an acoustic signal based on at least a portion of the received analog signal.

In an alternative embodiment of the present invention, a direct data path **114** is provided for communicating with the user interface unit **112**. This data path could carry the transmitted data stream, the received data stream or both. In embodiments of the present invention where the user interface unit **112** includes a processor, data path **114** is advantageous to allow direct digital communication without need for the conversion to analog and then back to digital data.

FIG. 7 presents a block diagram representation of an user interface unit in accordance with the present invention. In particular, user interface **112** of FIG. **6** is shown in more detail in accordance with various alternative embodiments.

User interface unit **112** optionally includes a telephone tip/ring converter **125** that converts the analog signal line **122** from the D/A converter **110** to appear as a typical tip/ring pair **127** to telephone line interface unit **120**. In particular, tip/ring converter **125** adds a voltage bias and provides any necessary generation or conversion of signal levels from line **122** to appear as a standard analog telephone line, even though the analog signals such as voice and ringing signals on line **122** where transported over a packet data line. In various embodiments of the present invention, the functionality of D/A converter **110**, A/D converter **108** and tip/ring converter **125** perform the functions of a line card used in conjunction with a digital central office switch.

Optional telephone line interface unit **120** provides an interface between processor **126** and tip/ring converter **125** by converting basic telephony signals such as on-hook, off-hook, and ring signals for detection by the processor or for generation by the processor to the tip/ring pair **127**. In this embodiment, keypad **134** and DTMF tone generator **128**, switch hook **132**, alert signal generator **130** and telephone handset **140** are further coupled to the tip/ring pair **127** for directly responding to, and/or for generating, the basic telephony signals carried by tip/ring pair **127** in a manner familiar to those skilled in the art.

While the present invention is described as including a switch hook, other similar devices could likewise be used, including a flash key or a receive button, within the scope of the present invention.

However, processor **126**, including a plurality of interface ports (not specifically shown) and general memory **144**, is likewise capable of responding to and/or directly generating the basic telephony signals in a similar manner. In this fashion, dialed numbers can be recorded and stored for redialing or speed dialing purposes, conditions requiring distinctive ringing patterns can be detected and distinctive rings can be generated, stored voice signals can be generated and received voice signals can be analyzed, and on-hook and off-hook signaling can be generated without the use of the switch hook.

In an alternative embodiment of the present invention the functionality supplied by tip/ring converter **125** and telephone interface unit **120** could be supplemented or supplanted by direct digital connection **114** to processor **126**. The plurality of interface ports (not specifically shown) of processor **126** could provide the appropriate conversion from the analog devices such as keypad **134** and DTMF tone generator **128**, switch hook **132**, alert signal generator **130** and telephone handset **140**.

In various embodiments of the present invention the user interface unit advantageously includes a display unit. In various embodiments, this display unit is a liquid crystal display (LCD) capable of displaying information relating to incoming and outgoing calls in additional to command and control information for the operation of the subscriber unit.

In particular, a graphical user interface (GUI) for operation of the telephone is implemented using the processor 126, the display device 136 and additional keys 138.

In a further embodiment of the present invention the additional keys are distributed adjacent to the display unit, the plurality of keys operable by the user to activate selected ones of a plurality of call control options displayed on the display device adjacent thereto. In this fashion, a plurality of call control options such as call transfer, hold, redial, conferencing, forwarding, speed dialing, hands free, line release, line selection, etc., can be implemented by a user by the presentation of a menu of commands and by pressing the key adjacent to the displayed command on the display device.

The display device 136 is further capable of displaying a plurality of data relating to an outgoing call, for instance, by monitoring the digits dialed by the user and by displaying destination telephone number reflected by these digits. The processor further is operable to time the duration of the call from the time the telephone line is off-hook and displaying the duration on the display device 136. Call memory 142 is available for storing the plurality of data relating to an outgoing call for a plurality of outgoing calls. This data can be retrieved and reviewed by the user or can be downloaded to an external device coupled to the subscriber unit through data interface unit 152.

Processor 126 is further capable of receiving and decoding caller identification data relating to the identity of an incoming caller and the display unit is capable of displaying a plurality of data relating an incoming call. In this fashion, caller ID signals received during the silent interval between the first and second rings of an incoming telephone call can be decoded and displayed to the user before the corresponding line is taken off-hook.

Similarly, for a subscriber to a caller ID/call waiting service who is engaged in a conversation with a first caller, the processor 126 can receive the caller ID information corresponding to a second caller and display it to a user for determination if the first caller should placed on hold and the second call should be answered. Additionally, the call disposition features corresponding a caller ID/call waiting deluxe could likewise be implemented using the display and either the keys of keypad 134 or the additional keys 138.

Call memory 142 is likewise available for storing a plurality of data relating to an incoming call for a plurality of incoming calls. The plurality of data relating the incoming call includes caller ID information of the calling party, the duration of the call (if the call was completed), and data indicating if the incoming call includes a facsimile message. In this embodiment of the present invention the stored data can be retrieved and displayed or downloaded as discussed earlier in conjunction with outgoing call data.

While many of the forgoing discussions have addressed the accessing of a single line, in various embodiments of the present invention the subscriber unit 100 is capable of monitoring and accessing multiple telephone lines, at least one of which is a derived digital telephone line. In these embodiments the display device 136 is capable of showing the status a plurality of lines, and the user is capable of accessing and placing calls on any one of a plurality of lines.

Further, the subscriber unit 100, through the use of processor 126 and in response to a signal generated by the user interface unit 112 and in response to an action of the user, is capable of initiating a connection to a remote central office on one or more derived digital telephone lines carried by the digital subscriber line. In this embodiment of the present invention the processor 126, coupled to the coder/decoder 106, and digital subscriber line interface 104, is capable of accepting data corresponding to a second derived digital telephone line in addition to a first derived digital telephone line, and the processor 126 is further capable of monitoring the status of the second derived digital telephone line. More generally, the subscriber unit 100, in response to a signal generated by the user interface unit 112 in response to an action of the user, is capable of initiating up to N additional derived digital telephone lines, where N is greater than 2.

In an additional embodiment of the present invention the user interface unit 112 further comprises a smart card interface unit 146 capable of accepting and communicating with a smart card (not specifically shown). Preferably, smart card interface unit 146 is compatible with PCMCIA standards and can accept any of a wide variety of such smart cards. In one such embodiment, the smart card inserted into the smart card interface unit 146 stores a plurality of data associated with the user and wherein the processor 126 is capable of downloading a plurality of smart card data from a smart card so that the use of the subscriber unit 100 can be personalized to the particular user.

In one embodiment of the present invention the plurality of smart card data includes a protocol address such as a IP node address or an ATM address corresponding to the user. In this fashion, the address of the telephone could change or be overridden by the address of the user downloaded from the smart card so that calls directed to the user could be sent to the particular subscriber unit 100 over a derived digital telephone line. Once the data was downloaded from the smart card, the subscriber unit can automatically register the presence of the subscriber at the location of the particular subscriber unit 100 by sending a data message to the remote central office over the digital subscriber line. Alternatively, the registration of the presence of the user at the particular subscriber unit 100 containing the smart card could be optionally effectuated only upon activation of the user either in response to a query by the subscriber unit, such as in response to a message displayed on the display device 136 or by action of the user in the absence of such a query.

In a further embodiment of the present invention the smart card data contains other personal options of the user including custom set-up and command options for the subscriber converter. These set-up and command options could include device macros for performing a series of commands on the subscriber unit at the touch of a single button and could also include a user's speed dial list.

In another embodiment of the present invention the user interface unit 112 further includes a keyboard 150 and wherein the subscriber unit is capable of communication with a first data service over the digital subscriber loop. In this fashion the subscriber unit 100 can operate as a PC or network computer to access data services such as internet or world wide web services from the subscriber unit 100. In one such embodiment the communication with the first data service over the digital subscriber loop could use data packets that do not correspond to a derived digital telephone line. However, one or more derived digital lines could, nevertheless, be used for this purpose. In this embodiment the user interface unit 112 further includes a display driver 148 for driving a remote display device. In an applications where communicating with a first data service the device driver 148 allows the use of a larger display than might be integrated in the subscriber unit itself.

In a further embodiment of the present invention, the subscriber unit 100 specifically includes the functionality of

a fax modem. In the fashion, the subscriber unit **100** is operable to send a receive a plurality of fax messages. In this embodiment a received fax message or fax message to be sent could be communicated to/from the subscriber unit using the data interface unit **152** in combination with a document scanner or a printer or other specific device.

In an additional embodiment of the present invention, the subscriber unit, under the control of processor **126**, performs the functionality of a answering machine where greetings are stored and played to incoming callers, and messages from callers are stored in a memory device such as general memory **144**.

FIG. **8** presents a perspective view of a subscriber unit in accordance with the present invention. In particular, a subscriber unit **100** is presented that incorporates the various features and options presented in conjunction with the descriptions of FIG. **6** and FIG. **7**. Housing **160** includes an integral display device **136**, keypad **134** and telephone handset **140**. Additional keys **138** (that are not adjacent to the display device **136**) and additional keys **138'** that are adjacent to the display device **136** provide access to advanced controls and features of the subscriber unit **100**. Smart card slot **162** corresponds to smart card interface unit **146** disposed within the housing. Display device jack **166** is coupled to display driver **148** within the housing **160** and data interface jack **164** is coupled to data interface unit **152** also disposed within the housing **160**.

FIG. **9** presents a perspective view of a subscriber interface unit in accordance with the present invention. In particular, FIG. **9** presents a subscriber interface unit for use in a telecommunication system including a switch, a local loop coupling the switch to a subscriber location. In this embodiment, a segment of the local loop includes copper twisted pair and the asymmetrical digital subscriber line is carried by the local loop. Further, the asymmetrical digital subscriber line carries a plurality of derived digital telephone lines as described in conjunction with FIGS. **1–5**. The subscriber interface unit of FIG. **9** advantageously couples the asymmetrical digital subscriber line to an analog land-line telephone.

Subscriber interface unit **180** includes a housing **182** having a top surface **184** and a bottom surface **186** substantially coplanar to the top surface. An electrical coupler **188** provides a connection to a cable capable of carrying the asymmetrical digital subscriber line. An RJ-11 jack **190** provides a connection to a cable of the analog telephone (not specifically shown). A converter **200**, disposed within the housing, coupled to the electrical coupler **188** and to the RJ-11 jack **190**, converts the first analog signals generated by the analog telephone into a first plurality of data packets for transmission to a selected one of the plurality of derived digital telephone lines and converts a second plurality of data packets received from the selected one of the plurality of derived digital telephone lines into a second analog signal for transmission to the analog telephone.

In a particular embodiment of the present invention the subscriber interface unit **180** includes several optional features that correspond to features described in conjunction with the subscriber unit **100**. Components that are common with subscriber unit **100** are assigned common reference numerals. In addition, subscriber unit **180** includes a first indented portion **192** of top surface **184** for accepting the analog telephone on top thereof. A plurality of non-skid feet are coupled to the bottom surface **186** of the housing **182**.

While an RJ-11 jack **190** is shown for coupling to the analog landline telephone, many other electrical connections including other plug and jack combinations are possible within the scope of this embodiment of the present invention. In a one embodiment of the present invention the digital subscriber line is carried by the standard telephone wiring within a home. In this embodiment, electrical coupler **188** is also implemented using an RJ-11 jack, however, like the RJ-11 jack **190**, other electrical connection options are possible within the broad scope of the present invention.

FIG. **10** presents a block diagram representation of a converter in accordance with the present invention. In particular, a converter **200** is presented for use with the subscriber interface unit **180** of FIG. **9**. Digital subscriber line **102** is attached to electrical coupler **188**. An analog land-line telephone is coupled to the converter via line **204** connected to RJ-11 jack **190**. Components that are common with subscriber unit **100** are assigned common reference numerals. Converter **200** operates in a manner similar to subscriber unit **100**, however, some of the components of subscriber unit **100** are supplied by an analog land-line telephone that is attached to the unit. In other words, the functionality of user interface unit **112** is supplied by interface unit **202** in combination with the analog land-line telephone. For the purposes of this disclosure the term "subscriber unit" should include the various embodiments of subscriber unit **100** as well as the various embodiments of subscriber interface unit **180** in combination with an analog land-line telephone.

In accordance with the present invention a multi-line analog telephone can be coupled to the subscriber interface unit **180**. In a manner similar to subscriber unit **100**, the combination of subscriber interface unit **180** and the multi-line analog land-line telephone is capable of accessing and monitoring the plurality of telephone lines and is further capable of selecting one of the plurality of telephone lines for conducting a voice call. The converter **200** further is capable of converting a third plurality of data packets received from an additional one of the plurality of derived digital telephone lines into a third analog signal for transmission to the analog telephone.

FIG. **11** presents a block diagram representation of an interface unit in accordance with the present invention. In particular, user interface unit **202** is shown for use in accordance with one embodiment of the converter **200** of FIG. **10**. Lines **122** and **124** from the A/D converter **108** and D/A converter **110** are coupled to tip/ring converter **125** as described in conjunction with several embodiments of subscriber unit **100**. The output **204** appears as a standard tip and ring pair to the analog land-line telephone.

The user interface unit **202** of FIG. **11** presents minimal functionality. The inclusion of additional functions for subscriber interface unit **180** can be desirable. In particular, many of the additional functions described in conjunction with subscriber unit **100** can likewise be included in subscriber interface unit **202** in accordance with the present invention. While the subscriber interface unit **180** of FIG. **9** does not present each of these additional functions, these functions may, nevertheless be included as described in conjunction with an alternative embodiment for interface unit **202** presented in FIG. **12**.

FIG. **12** presents a block diagram representation of an interface unit in accordance with the present invention. In particular, an alternative embodiment of interface **202** designated by reference numeral **202'** is presented. In this embodiment, numerous features of subscriber unit **100** are included. Components that are common with subscriber unit **100** are assigned common reference numerals. The output

204 of tip/ring converter 125 is coupled to the analog land-line telephone as well as to telephone line interface unit 120. Processor 126, display device 136, additional keys 138, call memory 142, general memory 144, smart card interface unit 146, display driver 148, keyboard 150 and data interface unit 152 function as previously described in conjunction with user interface unit 112.

FIG. 13 presents a flowchart representation of a method in accordance with the present invention. In particular, a method for initiating a call is presented for use with various embodiments of the subscriber unit 100 or the various embodiments of subscriber interface unit 180 in combination with an analog land-line telephone.

The method begins in step 300 receiving an off-hook signal, generated by the subscriber unit in response to an action of a user. In one embodiment of the present invention this signal would be generated by the switch hook of a subscriber unit responding to the handset going off-hook. In other embodiments, an off-hook signal could be generated by the user selecting an additional key of the subscriber unit such as a "handsfree" key used to initiate a call using a speakerphone function of the subscriber unit or a "send" key commonly used by cellular telephones to initiate a call.

The method continues in step 302 by initiating a first derived digital telephone line of the plurality of derived digital telephone lines in response to the off-hook signal. In particular, the off-hook signal is converted to data in a transmitted data stream that is converted to a transmitted data packet that is transmitted along the digital subscriber line to a switch through an interworking unit. This begins a data packet exchange between the switch and the subscriber unit carrying the basic telephony signals corresponding to the derived digital telephone line. In one embodiment of the present invention the data packet is addressed to an interworking unit where it is converted to a signaling protocol for interface to the switch.

FIG. 14 presents a flowchart representation of a method in accordance with the present invention. In particular, a method for initiating and terminating a call is presented for use with various embodiments of the subscriber unit 100 or the various embodiments of subscriber interface unit 180 in combination with an analog land-line telephone.

Steps 300 and 302 proceed as described in conjunction with the method described in connection with FIG. 12. The method continues in step 304 by generating a line-in-use signal, at the subscriber unit, indicating a first derived digital telephone line is in use. In step 306, a visual indicator is generated at the subscriber unit in response to the line-in-use signal. In a preferred embodiment of the present invention, the visual indicator includes a display, on display device 136, of the destination telephone number and of the duration of the call. Optionally, the visual display includes an indicator of an assigned number for the derived digital line. Thus, in a multi-line environment, a visual designator such as "line 1" can be displayed as well.

The method continues in step 308 by monitoring, at the subscriber unit, the content of at least one of the plurality of data packets of the digital subscriber line. In a preferred embodiment of the present invention, each of the incoming packets is continuously monitored by the subscriber unit to determine if any of the plurality of incoming data packets has an address corresponding to the subscriber unit. If so, the data payload from each such packet is transformed to the received data stream for transfer to the user interface unit to conduct the call. Further the transmitted data stream would be converted into a plurality of data packets addressed to the switch.

In step 310, an on-hook signal is received, generated by the subscriber unit in response to an action of a user. In one embodiment of the present invention this signal would be generated by the switch hook of a subscriber unit responding to the handset being placed on-hook. In other embodiments, an on-hook signal could be generated by the user selecting an additional key of the subscriber unit such as a "line release" key used to terminate a call using a speakerphone function of the subscriber unit.

In step 312 the derived digital telephone line is terminated in response to the on-hook signal. In particular, the call is terminated when the on-hook signal is transmitted to the switch and the subscriber unit stops creating a transmitted data stream and transmitted data packets. The exchange of data packets between the switch and the subscriber unit corresponding to the derived digital telephone line ends. In step 314, the visual display indicating the line is use is also terminated with the termination of the call.

FIG. 15 presents a flowchart representation of a method in accordance with the present invention. In particular, a method for responding to an incoming call is presented for use with various embodiments of the subscriber unit 100 or the various embodiments of subscriber interface unit 180 in combination with an analog land-line telephone. One of ordinary skill in the art will recognize, based on the disclosure herein, that this method may be used in conjunction with the other methods of the present invention described herein.

The method begins is step 320 by monitoring the content of at least one data packet to detect an incoming call. As previously discussed, in a preferred embodiment of the present invention the step of monitoring is performed continuously. Prior to the initiation of an outgoing call or the receipt of an incoming call, the step of monitoring is important to both the detection of usage of other derived digital lines and the detection of an incoming call for the particular subscriber unit. During a call the step of monitoring is important to identifying data packets that correspond to the call in progress.

The method continues in step 322 by determining if a received packet indicates an incoming call. After receiving a data packet addressed to the particular subscriber unit, the data portion of the packet is translated to a received data stream—the data indicating a ring signal from the central office. In response, the method initiates ringing as shown in step 324. In step 326, caller ID information, that is, in a preferred embodiment, transmitted between the silent interval between the first and second ringing signals, is decoded, displayed on the display device, and is stored in a call memory.

The method proceeds in step 328 to determine if an off-hook signal is received. If an off-hook signal is received, the call is conducted in step 330 by continuously sending and receiving data packets corresponding to a derived digital telephone line between the subscriber unit and the central office for the duration of the call. In step 332, a line-in-use signal is generated in response to the off-hook signal and in step 334 a visual indicator is generated and displayed to the user. In a preferred embodiment of the present invention this visual indicator includes the duration of the call and the received caller ID data. The visual indicator may optionally include a line designator indicating the line number of the line in use.

In step 336 the method proceeds by determining if an on-hook signal is generated in response to an action of the user. In step 338, in response to the detection of an on-hook

signal the derived digital line is terminated. The method continues by returning to step 320 and continuing to monitor the content of the incoming data packets for the initiation of an incoming call.

In a further embodiment of the present invention, when the remote party engaged in a telephone call on a derived digital telephone line goes on-hook, the subscriber unit generates an on-hook signal a predetermined time later to terminate the line in cases where the remote party has hung-up.

FIG. 16 presents a flowchart representation of a method in accordance with the present invention. In particular, a method for indicating the use of a derived digital telephone line by another subscriber unit is presented for use with various embodiments of the subscriber unit 100 or the various embodiments of subscriber interface unit 180 in combination with an analog land-line telephone. One of ordinary skill in the art will recognize, based on the disclosure herein, that this method may be used in conjunction with the other methods of the present invention described herein.

The method begins in step 340 by monitoring, at the subscriber unit, the content of at least one of the plurality of data packets corresponding to the digital subscriber line. The method continues in step 342 by determining that a first derived digital telephone line is in use based on the content of the at least one of the plurality of data packets.

In this embodiment of the present invention, the subscriber unit monitors the traffic of data packets to determine the presence of incoming and outgoing calls by other subscriber units that share the same digital subscriber line. In one such embodiment the addresses of the other subscriber units is recorded in the particular subscriber unit of interest so that packets addressed to the other subscriber units can be read. In an alternative embodiment of the present invention all incoming data packets are monitored for the presence of basic telephony signals to determine if other derived digital telephone lines are in use.

In step 344 a line-in-use signal is generated, at the subscriber unit, indicating a first derived digital telephone line is in use. This line-in-use signal can be used in the subscriber unit to display information on the status of one or more additional lines that are use by other subscriber units connected to the same digital subscriber line.

In operation, the present invention allows a plurality of subscriber units to be advantageously connected to a single subscriber line. The nature of the derived digital telephone line allows additional telephone lines to be added on demand up to the bandwidth limits of the digital subscriber loop. All of these lines can be monitored and accessed by a single subscriber unit connected to the digital subscriber line. The subscriber unit of the present invention is capable of performing the advanced features of a multi-line centrex-based system without the necessity of the additional hardware. For instance, each subscriber unit can perform three-way calling, call transfer, call forwarding, call holding etc.

FIG. 17 presents a flowchart representation of a method in accordance with the present invention. In particular, a more detailed method for indicating the use of a derived digital telephone line by another subscriber unit is presented for use with various embodiments of the subscriber unit 100 or the various embodiments of subscriber interface unit 180 in combination with an analog land-line telephone. One of ordinary skill in the art will recognize, based on the disclosure herein, that this method may be used in conjunction with the other methods of the present invention described herein.

Steps 340, 342 and 344 correspond to similar steps presented in conjunction with FIG. 16. Step 346 proceeds by generating a visual indicator in response to the line-in-use signal. In a preferred embodiment of the present invention this visual indicator includes the duration of the call, the received caller ID data. The visual indicator further includes a line designator indicating the line number of the line in use.

In step 348 an add-a-line signal is received, generated in response to an action by the user. In one embodiment of the present invention, this signal is generated by an off-hook signal where a line is currently in use. In this fashion the subscriber unit defaults to adding a new line rather than adding the user to a call on an existing line when the receiver is picked-up during a period when another derived digital telephone line is in use. In this embodiment, an existing call would be accessed by a user by pressing another key, such as a soft key, adjacent to the portion of display indicating that an call is progress. In an alternative embodiment the functions could be reversed and an off-hook signal would default to joining an existing call and an additional key could be used to generate an add-a-line signal.

The method proceeds in step 350 by initiating a second derived digital line by setting up two-way packet data communication with the local central office. Optional steps 352 and 354 correspond to receiving a hold signal generated by the action of the user, such a pressing a hold button, and placing the second derived digital line on "hold". Optional steps 356 and 358 correspond to receiving a signal based on the action of a user indicating one of a plurality of derived digital lines that are currently active and accessing the corresponding one of the plurality of derived digital lines.

In step 360 an on-hook signal is received and in step 362, the second derived digital line is terminated in response to the on-hook signal. These steps are similar in scope to steps described in conjunction with the methods of FIGS. 14 and 15.

FIG. 18 presents a block diagram of a wide area communication network 500 in accordance with the present invention. The network 500 has a first digital subscriber line 502 connected between a first network interface device (NID) 504 and digital subscriber line access multiplexer (DSLAM) 506. The NID 504 separates an ISDN (Integrated Services Digital Network) channel 508 from a digital subscriber channel 510. A protocol translator 512 is connected the a digital subscriber channel 510. The protocol translator converts between the ATM format of the DSL channel 510 and a local area network format, such as Ethernet (CDCS—Collision Sense Collision Detect). A hub 514 is connected to the protocol translator and a plurality of devices 516, 518. The hub 514 connects the plurality of devices together and may act as a repeater. An ISDN telephone 520 is connected to the ISDN channel 508.

The DSLAM 506 separates the digital subscriber channel from the ISDN channel 522. The ISDN channel 522 is connected to the PSTN (Public Switched Telephone Network) 523. The digital subscriber channel includes a first virtual circuit 524 connected to an asynchronous transfer mode network 526. An ISP (Internet Service Provider) 528 is connected to a second virtual circuit 530 of the digital subscriber channel. A local area network 532 is connected by the first virtual circuit 524 to the ATM network 526. Technically, the first virtual circuit 524 would extend from the protocol translator 512 to the LAN 532.

DSL lines are a service that runs over ordinary twisted pair (copper) wires. The DSL is connected between a central office of a telephone company to a subscriber location. DSL

uses the ATM (Asynchronous Transfer Mode) protocol to transport the data over the telephone wires. ATM is a connection oriented service. Before any data is transmitted a virtual circuit must be defined between the end points. In the case of prior art DSL services, a permanent virtual circuit is defined between the subscriber and an ISP. However, ATM specifies both permanent virtual circuits and switched virtual circuits. A switched virtual circuit is set up at the beginning of a session and torn down when the session is over, similar to a telephone call. A virtual circuit is defined by a virtual path identifier (VPI) and a virtual circuit identifier (VCI). These identifiers are included in the header of every ATM cell (packet). An ATM switch examines the VPI and VCI to determine how to switch the cell. Since the virtual circuit (path) has been defined before any data is sent, the ATM switch only need examine a small portion of the identifiers. This allows the ATM switch to switch the cell on the fly, as opposed to the store and forward approach of routers. This makes ATM more secure and faster than router systems such as the Internet. Note that the same physical medium and the same bandwidth can and commonly are used for more than a single virtual circuit. Thus in FIG. 18 the first virtual circuit **524**; the second virtual circuit **530** and the ISDN channel **508** are all carried over the single DSL line **502**.

FIG. 19 presents a block diagram of a wide area communication network **550** in accordance with the present invention. The network includes a first DSL **552** connected to a first NID **554**. The NID splits the ISDN channel (POTS channel) **556** from the digital subscriber channel **558**. An ISDN telephone **560** is connected to the ISDN channel **556**. In another embodiment two ISDN telephones are connected to the ISDN channel **556**. The ISDN channel **556** is a BRI (basic rate interface) ISDN channel and has two B-channels and one D-channel. The two B-channels allow two simultaneous telephone calls. The D-channel is used for control information, such as call setup. The B-channels can also be used for carrying data.

A protocol translator **562** is connected to the first NID **554**. A hub **564** is connected to the protocol translator **562**. The hub **564** connects together a local area network. The local area network can include a variety of electronic devices. For instance, a digital facsimile machine **566** is connected to the hub **564**. A digital facsimile machine **566** as used herein means a facsimile machine that is capable of sending and receiving facsimile information (digitized facsimile transmission) using a digital data standard as opposed to a facsimile machine that transmits and receives facsimile data (digitized facsimile transmission) over a POTS telephone line. A computer **568** is connected to the hub **564**. A subscriber unit **570** is connected to the hub **564**. A POTS telephone **572** and a POTS facsimile machine (facsimile machine) **574** are connected to the subscriber unit **570**. The subscriber unit **570** converts between the LAN format data and POTS signals.

A DSLAM **576** is connected to the DSL **552**. The ISDN channel **556** connects the DSLAM **576** to the PSTN (Public Switched Telephone Network) **578**. A second virtual circuit **580** of the digital subscriber channel is connected between an ISP **582** and the DSLAM **576**. A first virtual circuit **584** of the digital subscriber channel extends through the DSLAM **576**, ATM network **586** to a second DSL **588**. The second DSL **588** connects to a second local area network **590**. The second local area network includes an ATM switch **592**. A plurality of computers **594**, **596**, a digital facsimile machine (network facsimile machine) **598** and a second subscriber unit **600** are connected to the ATM switch **592**. A POTS telephone **602** is connected to the subscriber unit **600**. In one embodiment the subscriber unit and telephone are combined to form a network telephone.

FIG. 20 presents a block diagram of a wide area communication network **620** in accordance with the present invention. The network **620** has a first subscriber location **622**. A first network interface device (NID) **624** is attached to the first subscriber location **622**. A first digital subscriber line **626** connects the NID **624** to a first digital subscriber line access multiplexer (DSLAM) **628**. The DSLAM **628** is coupled to an ATM network **630**. A second digital subscriber line access multiplexer (DSLAM) **632** is connected to the ATM network **630**. A public switched telephone network (PSTN) **634** connects the first DSLAM **628** to the second DSLAM **632**. A second digital subscriber line **636** connects the second DSLAM **632** to a second subscriber location **638**. In one embodiment the second subscriber location **638** is attached to a second NID.

FIG. 21 presents a block diagram of a wide area communication network **650** in accordance with the present invention. A first subscriber location **652** includes a first LAN **654** and a first telephone system **656** connected to a NID **658**. The LAN **654** includes a network facsimile machine **660** and a subscriber unit **662**. A POTS telephone **664** and POTS facsimile machine **666** are connected to the subscriber unit **662**. The subscriber unit converts between an analog telephone signal and a digital telephone signal. An ISDN facsimile machine **668** is connected to the telephone system **656**. An ISDN facsimile machine is a facsimile machine that is capable of communicating facsimile information over an ISDN line.

A first DSL **670** connects the NID **658** to a first DSLAM **672**. An ATM network **674** is connected to the DSLAM **672**. A second DSLAM **676** is connected to the ATM network **674**. A second digital subscriber line **678** connects a second subscriber location **680** to the second DSLAM **676**. A first ISP **682** and a second ISP **684** are connected to the ATM network **674**. The internet **686** connects the first ISP **682** and the second ISP **684**. An interworking unit (IWU) **688** is connected to the DSLAM **672**. The IWU converts between a packet data format and a circuit switch data format. A PSTN **690** connects the IWU to the DSLAM **676**. In one embodiment the telephone signal from the telephone **664** is carried by a telephone virtual circuit. In another embodiment the telephone virtual circuit terminates at the ISP **682**. In this embodiment the telephone signal is carried by the internet for a portion of the call. In another embodiment, the telephone circuit terminates at the interworking unit. The call is then routed as a standard circuit switched call. In one embodiment a digitized facsimile transmission from (to) the digital facsimile machine **660** is carried by a facsimile virtual circuit. In one embodiment, the telephone system receives a POTS signal from the NID **658**. In this case the telephone or facsimile machine connected to the telephone system must be a POTS device.

This system allows a small business to setup a communication network over a digital subscriber line. The communication network includes computer data, voice signals and facsimile signals.

FIG. 22 presents a block diagram of a wide area communication network **700** in accordance with the present invention. A first subscriber location **702** includes a first local area network **704** and a first telephone system **706**. The first LAN **704** and telephone system **706** are connected to a first NID **708**. A first DSL line **710** is connected to the NID **708**. A first DSLAM **712** is connected to the first DSL line **710**. The DSLAM **712** separates the a first DSL channel **714** from a

first telephony channel 716. A public switched telephone network 718 is connected to the first telephony channel 716. An ATM network 720 is connected to the first DSL channel 714. A second DSLAM 722 is connected to the ATM network by a second DSL channel 724. The second DSLAM 722 is connected to the PSTN 718 by a second telephony channel 726. A second DSL line 728 is connected to the second DSLAM 722. A second NID 730 attached to a second subscriber location 732 is connected to the second DSL line 728. A second local area network 734 and a second telephone system 736 are connected to the second NID 730.

FIG. 23 presents a block diagram of a wide area communication network 750 in accordance with the present invention. A first subscriber location 752 in a first local access and transport area (LATA) 754 includes a first LAN 756 and a first telephone system (TS-1) 758. Note the telephone system can consist of a single POTS line or a single BRI ISDN line and the telephone (or computer) equipment that can be connected to the line. The first LAN 756 and first telephone system 758 are connected to a first NID 760. The first LAN 756 includes a first computer 762, a subscriber unit 764 and a network facsimile machine 766. A telephone 768 is connected to the subscriber unit 764. A telephone 770 is part of the first telephone system 758. A first DSL line 772 connects a first DSLAM 774 to the NID 760. The DSLAM 774 is connected to an ATM network 776 by a first DSL channel 778. A PSTN 780 is connected to the DSLAM 774 by a first telephony channel 782 and by an IWU 784. A second DSL channel 786 connects the ATM network 776 to a second DSLAM 788. A second telephony channel 790 connects the PSTN 780 to the DSLAM 788. A second DSL line 792 connects a DSLAM 788 to a second NID 794. The NID 794 is attached to the second subscriber location 796 in a second local access and transport area (LATA) 798. The second subscriber location includes a second LAN 800 and a second telephone system 802 connected to the NID 794. A second computer 804 is connected to the LAN 800. A second telephone 806 and a facsimile machine 808 are part of the second telephony system 802.

A first ISP 810 is connected to the ATM network 776. The ISP 810 is connected to an internet POP (point of presence) 812 by the internet 814. The internet POP 812 connects to the second DSL line 792 via an central office—service switching point (CO/SSP) 814. In one embodiment a first virtual circuit couples the first computer 762 to a second computer 804. The first virtual circuit is carried by the first DSL line 772, the ATM network 776 and the second DSL line 792. In another embodiment, a first switched circuit connects the first telephone 770 to a second telephone 806. The first switched circuit connects across the first DSL line 772, the PSTN 780 and the second DSL line 792. In another embodiment, a network telephone 768 is connected to the second telephony system 802 by a first hybrid circuit. The first hybrid circuit includes a second virtual circuit connecting the first LAN 756 to the IWU 784. A second switched circuit connects the IWU 784 to the second DSL line 792 through the PSTN 780. The second telephony channel 790 connects to the second telephone 806. In another embodiment the first hybrid circuit includes a second virtual circuit connecting the first LAN 756 to the DSLAM 774, to the ATM network 776 and to the ISP 810. An internet telephony circuit connects the ISP 810 through the internet 814 to the internet POP 812. A second switched circuit connects the internet POP 812 to the second DSL 792. The second telephony channel connects the DSL 792 to the second telephone 806. Note that the term "internet circuit" is used to describe the routing of the call data through the internet. In another embodiment a second hybrid circuit connects the digital facsimile machine 766 to the facsimile machine 808. The second hybrid circuit includes a third virtual circuit connecting a first LAN 756 to the DSLAM 774 and then to the IWU 784. A third switched circuit connects the IWU 784 to the second DSL line 792 through the PSTN 780. The second telephony channel connects the DSL 792 to the facsimile machine 808.

The network described above allows small business to setup wide area communication networks that can transmit a variety of types of data. The data types include computer data, voice signals, facsimile signals and video signals. As will be apparent to those skilled, in light of the foregoing description, almost any type of data (signal) can be sent over the wide area network. The communication network takes advantage of DSL services that provide access to both packet (cell) switched or routed networks and circuit switched networks. In addition, the wide area network is easily reconfigurable as the business moves and expands.

The various methods described herein, in a preferred embodiment, are intended for operation as software programs running on a computer processor. One of ordinary skill in the art will recognize that other hardware implementations such as bridges and routers could be used. It should also be noted that the various methods of the present invention could be stored on a tangible storage medium such as a magnetic or optical disk, read-only memory or random access memory and be produced as an article of manufacture.

Thus, there has been described herein a concept, as well as several embodiments including a preferred embodiment, of a wide area communication network. The various embodiments of methods and systems, by enabling a wide area communication network over digital subscriber lines, provide a significant improvement over the prior art. Additionally, the various embodiments of the present invention herein-described have other features that distinguish the present invention from the prior art.

It will be apparent to those skilled in the art that the disclosed invention may be modified in numerous ways and may assume many embodiments other than the preferred forms specifically set out and described above. Accordingly, it is intended by the appended claims to cover all modifications of the invention which fall the true spirit and scope of the invention.

What is claimed is:

1. A wide area communications network, comprising:

a first digital subscriber line;

a first network interface device connected to the first digital subscriber line, the first network interface device separating an ISDN channel from a digital subscriber channel;

an ISDN telephone connected to the network interface device;

a protocol translator connected to the network interface device by the digital subscriber channel;

a hub connected to the protocol translator;

a plurality of devices connected to the hub;

a digital subscriber line access multiplexer connected to the first digital subscriber line, the digital subscriber line access multiplexer separating the digital subscriber channel from the ISDN channel;

a public switched telephone network connected to the ISDN channel;

an asynchronous transfer mode network connected to the digital subscriber line access multiplexer by a first virtual circuit of the digital subscriber channel;

an ISP connected to the digital subscriber line access multiplexer by a second virtual circuit of the digital subscriber channel; and

a local area network connected to the asynchronous transfer mode network by the first virtual circuit.

2. The system of claim 1, wherein the plurality of devices include a computer.

3. The system of claim 1, wherein the plurality of devices include a subscriber unit and a telephone connected to the subscriber unit.

4. The system of claim 3, further including a facsimile machine connected to the subscriber unit.

5. The system of claim 1, further including a digital facsimile machine connected to the hub.

6. The system of claim 1, further including a second digital subscriber line connecting the local area network to the asynchronous transfer mode network.

7. The system of claim 6, wherein the local area network includes an ATM switch.

8. The system of claim 7, further including a plurality of computers connected to the ATM switch.

9. The system of claim 8, further including a second subscriber unit connected to the local area network.

10. The system of claim 9, further including a POTS telephone connected to the subscriber unit.

11. The system of claim 10, further including a facsimile machine coupled to the ATM switch.

* * * * *

P

US006198745B1

(12) **United States Patent**
Brodigan

(10) **Patent No.: US 6,198,745 B1**
(45) **Date of Patent: Mar. 6, 2001**

(54) **ATM BASED VDSL COMMUNICATION SYSTEM FOR PROVIDING VIDEO AND DATA ALARM SERVICES**

(75) Inventor: **Donald L. Brodigan**, Broomfield, CO (US)

(73) Assignee: **Qwest Communications International Inc.**, Denver, CO (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/339,156**

(22) Filed: **Jun. 24, 1999**

(51) **Int. Cl.**[7] **H04L 12/56**

(52) **U.S. Cl.** **370/395**

(58) **Field of Search** 370/395, 230, 370/235, 397, 398, 399, 229, 231, 396, 237, 464, 465, 389; 379/93.15, 93.14, 100.13, 188, 189, 191, 198, 219, 220; 351/139, 118, 109, 113, 147

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,044,079 * 3/2000 Calvignac et al. 370/230
6,046,983 * 4/2000 Hasegawa et al. 370/395

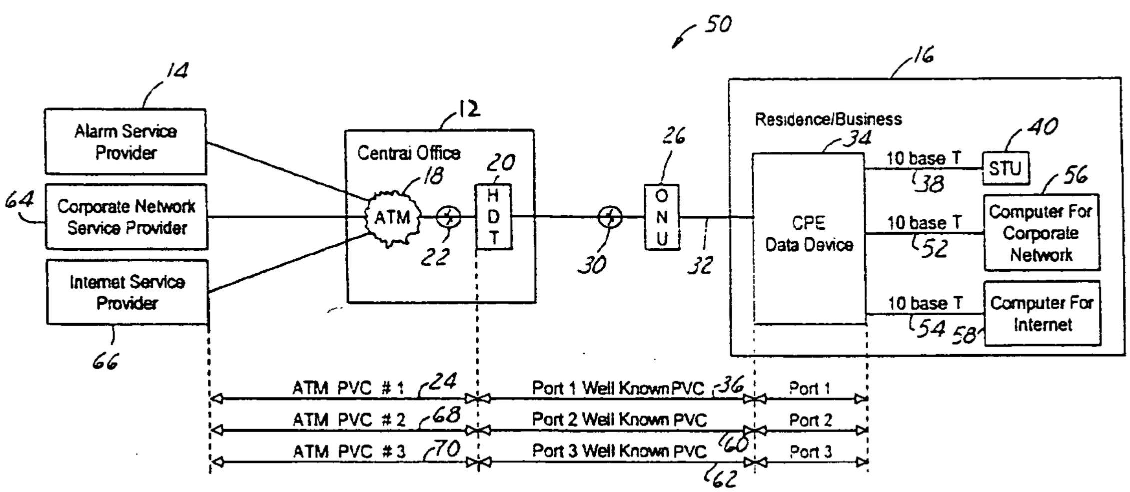
* cited by examiner

Primary Examiner—Dang Ton
(74) *Attorney, Agent, or Firm*—Brooks & Kushman P.C.

(57) **ABSTRACT**

An asynchronous transfer mode (ATM) based very-high-bit-rate digital subscriber line (VDSL) communication system for providing alarm services between an alarm service provider and a subscriber includes an ATM network connected to an alarm service provider. A host digital terminal is connected to the ATM network by an ATM permanent virtual circuit. The host digital terminal and the alarm service provider communicate alarm signals on the ATM permanent virtual circuit through the ATM network. A customer provided equipment (CPE) data device is connected through the optical network unit to the host digital terminal by a well known VDSL permanent virtual circuit. The well known VDSL permanent virtual circuit is supported on a fiber optics link between the host digital terminal and the optical network unit and a twisted pair link between the optical network unit and the CPE data device. The CPE data device and the host digital terminal communicate alarm signals on the well known VDSL permanent virtual circuit. A subscriber terminal unit is connected to the CPE data device for communicating alarm signals with the CPE data device. The host digital terminal connects the ATM permanent virtual circuit and the well known VDSL permanent virtual circuit to communicate the alarm signals between the alarm service provider and the subscriber terminal unit.

20 Claims, 2 Drawing Sheets



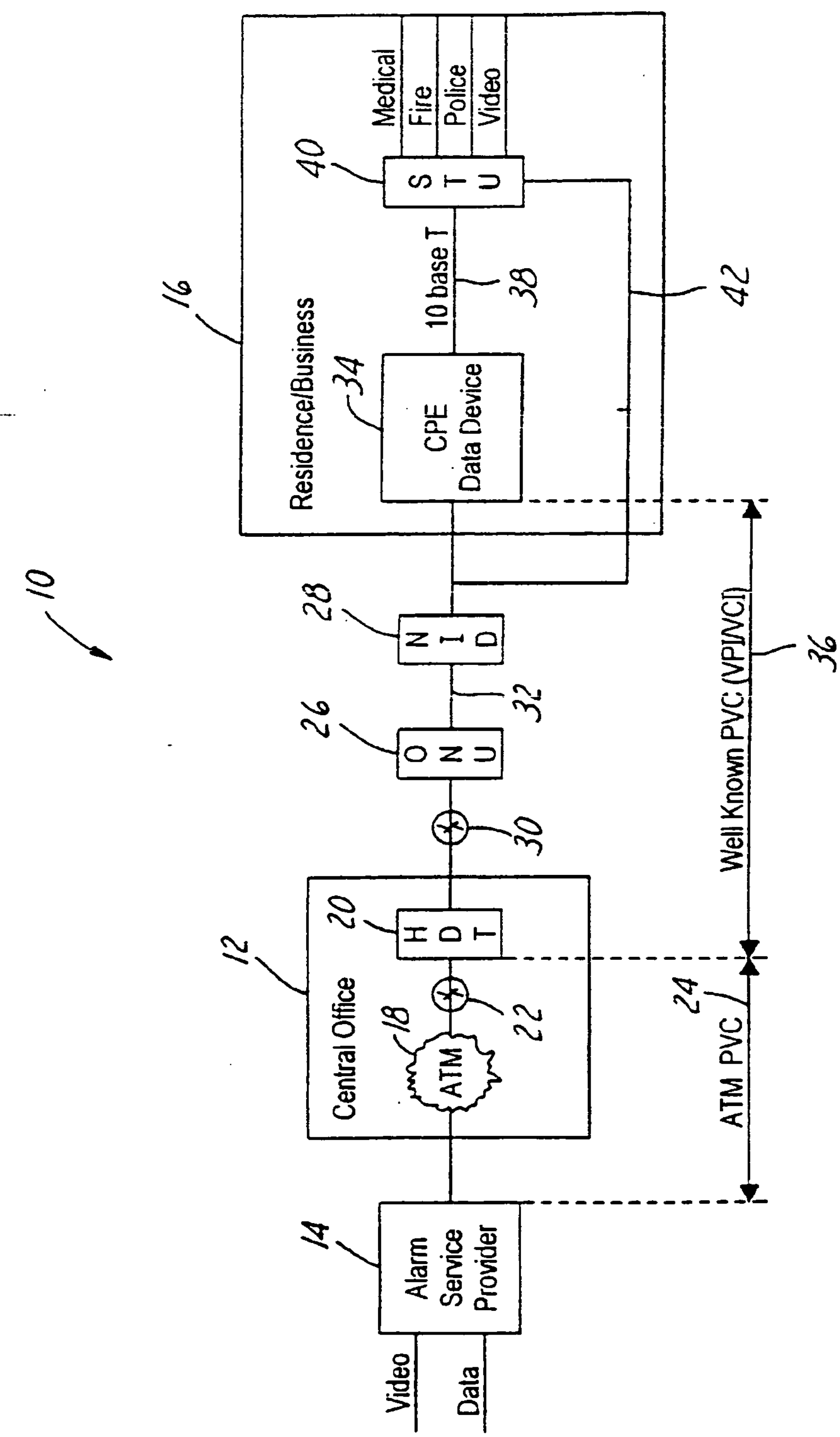

10
Residence/Business
16
CPE
Data Device
34
10 base T
38
S
T
U
40
Medical
Fire
Police
Video
42
N
I
D
28
O
N
U
26
32
30
Central Office
12
H
D
T
20
ATM
18
22
Alarm
Service
Provider
14
Video
Data
Well Known PVC (VPI/VCI)
36
ATM PVC
24

FIG. 1

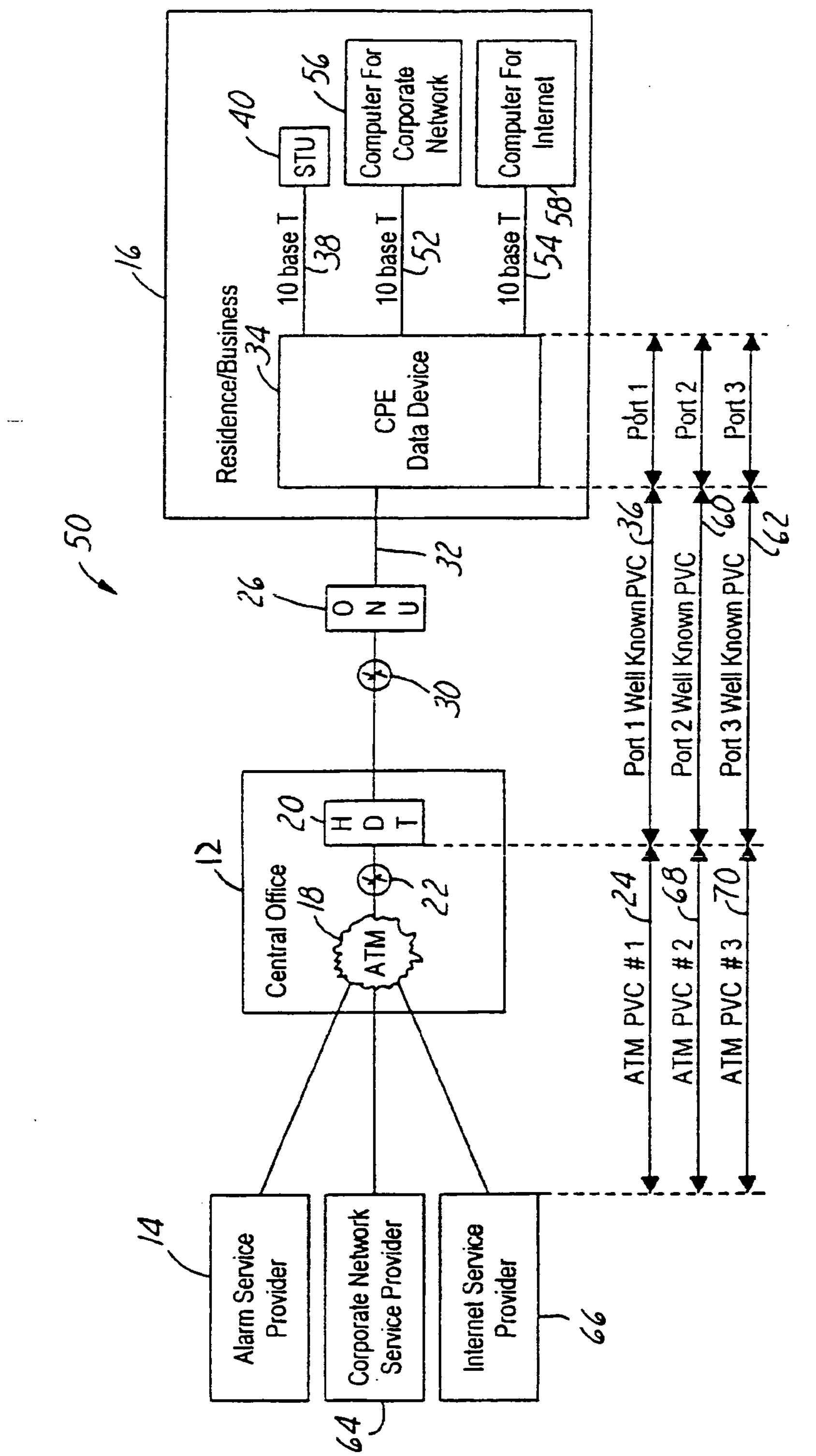

Residence/Business
CPE
Data Device
STU
Computer For
Corporate
Network
Computer For
Internet
10 base T
10 base T
10 base T
Port 1
Port 2
Port 3
O
N
U
Central Office
H
D
T
ATM
Port 1 Well Known PVC
Port 2 Well Known PVC
Port 3 Well Known PVC
ATM PVC #1
ATM PVC #2
ATM PVC #3
Alarm Service
Provider
Corporate Network
Service Provider
Internet Service
Provider
50
16
40
56
38
52
54
58
34
36
60
62
32
26
30
12
20
18
22
24
68
70
14
64
66

FIG. 2

ATM BASED VDSL COMMUNICATION SYSTEM FOR PROVIDING VIDEO AND DATA ALARM SERVICES

TECHNICAL FIELD

The present invention relates generally to asynchronous transfer mode (ATM) based very-high-bit-rate digital subscriber line (VDSL) communications for providing video and data services and, more particularly, to an ATM based VDSL communication system for providing video and data alarm services between an alarm service provider and a subscriber.

BACKGROUND ART

Alarm service providers have provided alarm services to their customers using telephone dial systems, limited low speed data on metallic copper wire pair systems, low speed wireless systems, and dedicated line services. In general, these systems transmit data too slow, are too expensive, and require too many resources to satisfy the demand for providing alarm services to a greater mass of subscribers. Very-high-bit-rate subscriber line (VDSL) communication systems provide high speed video and data transmission between service providers and their subscribers at a relatively low cost with fewer resources needed per subscriber. For the foregoing reasons, there is a need for an ATM based VDSL communication system and associated method for providing video and data alarm services between an alarm service provider and a subscriber that overcome the limitations of the prior art.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an asynchronous transfer mode (ATM) based very-high-bit-rate digital subscriber line (VDSL) communication system for providing video and data alarm services between an alarm service provider and a subscriber.

It is another object of the present invention to provide an ATM based VDSL communication system in which video and data alarm services provided by an alarm service provider to a subscriber can be switched between data alarm services during normal conditions and video alarm services during alarm conditions.

It is a further object of the present invention to provide an ATM based VDSL communication system in which an alarm service provider can share the same twisted pair drop with another information provider to a subscriber.

In carrying out the above objects and other objects, the present invention provides an asynchronous transfer mode (ATM) based very-high-bit-rate digital subscriber line (VDSL) communication system for providing alarm services between an alarm service provider and a subscriber. The ATM based VDSL communication system includes an ATM network connected to an alarm service provider. A host digital terminal is connected to the ATM network by an ATM permanent virtual circuit. The ATM permanent virtual circuit is supported on a fiber optics link. The host digital terminal and the alarm service provider communicate alarm signals on the ATM permanent virtual circuit through the ATM network. An optical network unit is connected to the host digital terminal by a fiber optics link. A customer provided equipment (CPE) data device is connected through the optical network unit to the host digital terminal by a well known VDSL permanent virtual circuit. The well known VDSL permanent virtual circuit is supported on a fiber optics link between the host digital terminal and the optical network unit and a twisted pair link between the optical network unit and the CPE data device. The CPE data device and the host digital terminal communicate alarm signals on the well known VDSL permanent virtual circuit. A subscriber terminal unit is connected to the CPE data device for communicating alarm signals with the CPE data device. The host digital terminal connects the ATM permanent virtual circuit and the well known VDSL permanent virtual circuit to communicate the alarm signals between the alarm service provider and the subscriber terminal unit.

Preferably, the ATM permanent virtual circuit is selected by the host digital terminal from a plurality of ATM permanent virtual circuits for connection to the well known VDSL permanent virtual circuit. The host digital terminal switches between a first ATM permanent virtual circuit for communicating data alarm signals between the alarm service provider and the subscriber terminal unit and a second ATM permanent virtual circuit for communicating video alarm signals between the alarm service provider and the subscriber terminal unit. The host digital terminal switches between the first and second ATM permanent virtual circuits in response to an ATM permanent virtual circuit request data signal from the subscriber terminal unit.

Further, in carrying out the above objects and other objects, the present invention provides another ATM based VDSL communication system having an ATM network connected to an alarm service provider and an information service provider. A host digital terminal is connected to the ATM network by first and second ATM permanent virtual circuits. The first and second ATM permanent virtual circuits are supported on a fiber optics link. The host digital terminal and the alarm service provider communicate alarm signals on the first ATM permanent virtual circuit through the ATM network. The host digital terminal and the information service provider communicate information signals on the second ATM permanent virtual circuit through the ATM network. An optical network unit is connected to the host digital terminal by a fiber optics link. A customer provided equipment (CPE) data device is connected through the optical network unit to the host digital terminal by first and second well known VDSL permanent virtual circuits. The first and second well known VDSL permanent virtual circuits are supported on a fiber optics link between the host digital terminal and the optical network unit and a twisted pair link between the optical network unit and the CPE data device. The CPE data device and the host digital terminal communicate alarm signals on the first and second well known VDSL permanent virtual circuits. A subscriber alarm terminal unit is connected to the CPE data device by a first 10baseT port for communicating alarm signals with the CPE data device. A subscriber information terminal unit is connected to the CPE data device by a second 10baseT port for communicating information signals with the CPE data device. The host digital terminal connects the first ATM permanent virtual circuit and the first well known VDSL permanent virtual circuit to communicate the alarm signals between the alarm service provider and the subscriber alarm terminal unit and connects the second ATM permanent virtual circuit and the second well known VDSL permanent virtual circuit to communicate the information signals between the information service provider and the subscriber information terminal unit.

The above objects and other objects, features, and advantages of the present invention will be apparent from the following detailed description of the best mode for carrying out the invention when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 illustrates an ATM based VDSL communication system in accordance with a preferred embodiment of the present invention; and

FIG. 2 illustrates an ATM based VDSL communication system in accordance an alternate embodiment of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Referring now to FIG. 1, an asynchronous transfer mode (ATM) based very-high-bit-rate digital subscriber line (VDSL) communication system 10 in accordance with a preferred embodiment of the present invention is shown. ATM is a high bandwidth, low-delay, connection-oriented, packet-like switching and multiplexing technique. ATM transmissions are cell-based, with cells having a fixed length. Information is presented to the network asynchronously. However, the switches and interlinking transmission facilities are synchronized. Of course, it is to be appreciated that the term "asynchronous transfer mode" as used herein is meant to encompass equivalent network architectures in addition to traditional ATM.

VDSL services are of particular interest for a hybrid local loop scenario. In particular, communication system 10 is suitable for fiber-to-the-neighborhood (FTTN), fiber-to-the-curb (FTTC), and fiber-to-the-home (FTTH) distribution. The various distribution formats are collectively referred to as FTTX. Communication system 10 provides a private line like connection between an alarm service provider and a subscriber so that the alarm service provider can provide video and data alarm services to the subscriber. The data alarm services include text type alarms. The video alarm services include still picture and motion video surveillance.

Communication system 10 includes a central office 12 connecting an alarm service provider 14 to a subscriber 16 such as a residence or business. Central office 12 includes an ATM network 18 and a host digital terminal (HDT) 20 connected together by a fiber optic link 22. Alarm service provider 14 includes an ATM switch (not specifically shown) for connecting to central office 12 via ATM network 18. Alarm service provider 14 transmits and receives data alarm signals to and from central office 12. Central office 12 transmits and receives these data alarm signals to and from subscriber 16. Similarly, alarm service provider 14 receives video alarm signals from the central office via ATM network 18. Central office 12 receives these video alarm signals from subscriber 16.

A soft ATM permanent virtual circuit 24 connects alarm service provider 14 to HDT 20 through ATM network 18. Alarm service provider 14 communicates with central office 12 through ATM PVC 24. HDT 20 selects ATM PVC 24 from a pool of available PVCs for alarm service provider 14 and the alarm service provider has its own service handle assigned to the ATM PVC termination at the HDT. A service handle identifies the data rates that the ATM PVC can handle. For instance, 256 Kbps or 1 Mbps. HDT 20 maintains the ATM parameters associated with ATM PVC 24. ATM PVC 24 can have various cell and bit rates such as constant bit rate (CBR), variable bit rate (VBR), available bit rate (ABR), and undefined bit rate (UBR) which are maintained in a database of HDT 20. Using ATM PVC 24 allows alarm service provider 14 to control its own service applications, Internet Protocol (IP) addresses, and security issues transparently to the VDSL network connecting subscriber 16 to HDT 20.

Central office 12 and subscriber 16 communicate using VDSL through an optical network unit (ONU) 26 and a network interface device (NID) 28. A fiber optics link 30 connects HDT 20 to ONU 26. HDT 20 can support typically up to sixty four ONUs. ONU 26 converts optical signals to electronic signals to communicate with NID 28 via a twisted pair drop 32. ONU 26 can support up to thirty two drops. NID 28 connects to a customer provided equipment (CPE) data device 34 of subscriber 16. HDT 20 of central office 12 and CPE data device 34 of subscriber 14 communicate though a well known PVC 36 having a virtual path identifier (VPI) and a virtual channel identifier (VCI). Well known PVC 36 is a digital subscriber line (DSL) for HDT 20 and CPE data device 34 to communicate using VDSL. Well known PVC 36 has sufficient bandwidth for supporting video and data communication. HDT 20 connects ATM PVC 24 with well known VDSL PVC 36 to establish a private line like connection between alarm service provider 14 and subscriber 16.

CPE data device 34 has a 10baseT port 38 for communicating with a subscriber terminal unit (STU) 40. STU 40 is connected to at least one of a various security monitors. The security monitors can be home security, medical, fire, police, or video monitors, etc. These monitors monitor the security conditions of the residence or business of subscriber 16. In response to the monitoring, STU 40 transmits video and data alarm signals from the security monitors to alarm service provider 14 through a system PVC consisting of ATM PVC 24 and well known VDSL PVC 36, i.e., the private line like connection between subscriber 16 and the alarm service provider. STU 40 receives data alarm signals from alarm service provider 14 for the security monitors through ATM PVC 24 and well known VDSL PVC 36. These data alarm signals from alarm service provider 14 enable the alarm service provider to control the security monitors via STU 40. STU 40 has its own IP address which is used by alarm service provider 14 for communicating with the STU.

Generally, alarm service provider 14 transmits data alarm signals to STU 40. In response, STU 40 polls the security monitors to determine if conditions are proper and, if so, then transmits a data acknowledgment signal back to the alarm service provider. These data signals require relatively low bandwidth and consume relatively low system resources. If an alarm condition presents itself, alarm service provider 14 and STU 40 can switch from communicating data alarm signals to communicating video alarm signals. Video alarm signals require relatively high bandwidth and consume more system resources. Switching between video and data alarm signals is accomplished by STU 40 transmitting a meta signaling data signal along well known VDSL PVC 36 to HDT 20. In response to the meta signaling data signal, HDT 20 provisions an ATM PVC for alarm service provider 14, i.e., ATM PVC 24, having sufficient bandwidth for communicating video alarm signals. HDT 20 then connects this ATM PVC with well known VDSL PVC 36 for establishing a private line like connection between alarm service provider 14 and subscriber 16. STU 40 then transmits video alarm signals to alarm service provider 14 along the private line like connection. Alarm service provider 14 can also control the switching between video and data alarm signals by instructing STU 40 to request a switch. In response to this request, STU 40 transmits the meta signaling data signal to HDT 20.

STU 40 may be connected to several video monitors or a monitor that can move. Alarm service provider 14 transmits control signals to STU 40 for controlling which monitor is

to transmit video alarm signals to the alarm service provider. Alarm service provider 14 also transmits control signals to STU 40 for moving a movable monitor that is transmitting video signals to the alarm service provider.

Communication system 10 further includes a telephone line 42 connecting STU 40 to NID 28 while bypassing CPE data device 34. Telephone line 42 is a backup for enabling communication between alarm service provider 14 and STU 40 in the event of a power outage.

In operation, subscriber 16 wishes to subscribe with alarm service provider 14 to receive alarm services from the alarm service provider. In response, HDT 20 adds the service handle associated with alarm service provider 14 to the subscriber's user profile stored in the HDT. This service handle is added in the same manner as a video channel is added to a user video entitlement profile. After CPE data device 34 is powered on, HDT 20 establishes a connection between ATM PVC 24 and well known VDSL PVC 36 to connect alarm service provider 14 and subscriber 16 over a private line like connection, i.e., an established system PVC. Alarm service provider 14 assigns a unique IP address to STU 40. STU 40 then transmits a connect data signal over the established PVC to alarm service provider 14. If the established PVC between alarm service provider 14 and STU 40 is broken, the STU 40 continues to reestablish a connection to the alarm service provider 14 via telephone line 42. Alarm service provider 14 enables the video and data alarm services for STU 40 upon receiving the connect data signal from STU 40.

Alarm service provider 14 then transmits a polling data signal to STU 40 to ping the STU at predefined intervals. In response to receiving a polling data signal, STU 40 determines if an alarm condition is present. If an alarm condition is not present, STU 40 transmits an acknowledgment data signal back to alarm service provider 14 in response to the pinging. Failure to receive an acknowledgment signal causes alarm service provider 14 to generate an alarm condition. STU 40 can also detect the absence of pinging and generate an alarm condition. These polling and acknowledgment signals require relatively little bandwidth and, thus, ATM PVC 24 can be set at a low data rate such as 128 Kbps or 256 Kbps.

STU 40 also receives video signals from a video monitor and transmits these video signals to alarm service provider 14. The video signals are digital signals and may have different data rates depending upon whether still pictures, motion, or MPEG video is being transmitted. HDT 20 provisions an ATM PVC having sufficient bandwidth for handling the video signals. STU 40 may be connected to one of several monitors in which one monitor is transmitting video signals to the STU at a given time. Alarm service provider 14 can transmit control data signals to STU 40 to control which video monitor is transmitting video signals to the STU at a given time. Alarm service provider 14 then receives the video signals from the chosen video monitor via STU 40. This enables subscriber various locations to be monitored based on time or demand.

As indicated above, alarm service provider 14 and subscriber 16 can switch between communicating video and data alarm signals based on alarm conditions. Initially, host digital terminal 20 selects a first ATM PVC for connection to well known VDSL PVC 36 to communicate data alarm signals between alarm service provider 14 and subscriber 16. The first ATM PVC provides a sufficient bandwidth for the relatively low speed data alarm signals. In response to a request by STU 40, HDT 20 selects a different ATM PVC for connection to well known VDSL PVC 36 to communicate video alarm signals between alarm service provider 14 and subscriber 16. The second ATM PVC provides a sufficient bandwidth, for the relatively high speed video alarm signals.

Referring now to FIG. 2, an ATM based VDSL communication system 50 in accordance with an alternate embodiment of the present invention is shown. Communication system 50 has many of the same elements as communication system 10 and like elements have the same reference numerals. Communication system 50 generally differs from communication system 10 in that CPE data device 34 supports multiple 10baseT ports 38, 52, and 54 for connection to multiple devices. Communication system 50 is configured so that each of the multiple devices communicate with a respective service provider connected to ATM network 18.

STU 40 is connected to CPE data device 34 by 10baseT port 38. STU 40 is also connected to a first device 56 such as a computer for a corporate network by 10baseT port 52 and a second device 58 such as a computer for the Internet by 10baseT port 54. Each 10baseT port 38, 52, and 54 has an associated well known VDSL PVC 36, 60, and 62, respectively, for connection to HDT 20 of central office 12. Alarm service provider 14 is connected to HDT 20 by ATM PVC 24. Similarly, a corporate network service provider 64 and an Internet service provider 66 are connected to HDT 20 by ATM PVC 68 and ATM PVC 70, respectively. HDT 20 connects ATM PVC 24 with well known VDSL PVC 36 for enabling alarm service provider 14 and STU 40 to communicate over a first private line like link, i.e., a first system PVC. HDT 20 connects ATM PVC 68 with well known VDSL PVC 60 for enabling corporate network service provider 64 and corporate computer 56 to communicate over a second private line like link, i.e., a second system PVC. HDT 20 connects ATM PVC 70 with well known VDSL PVC 62 for enabling Internet computer 58 and Internet service provider 66 to communicate over a third private line like link, i.e., a third system PVC. An advantage of communication system 50 is that three private line like links are established over a single twisted pair drop 32. This means that alarm service provider 14 shares the same physical drop with other information service providers such as Internet service provider 66, thereby making efficient use of system resources.

Thus, it is apparent that there has been provided, in accordance with the present invention, an ATM based VDSL communication system for providing video and data alarm services that fully satisfy the object, aims, and advantages set forth above. While the present invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications, and variations will be apparent to those skilled in the art in light of the foregoing description. Accordingly, it is intended to embrace all such alternatives, modifications, and variations as fall within the spirit and broad scope of the appended claims.

What is claimed is:

1. An asynchronous transfer mode (ATM) based very-high-bitrate digital subscriber line (VDSL) communication system for providing alarm services between an alarm service provider and a subscriber, the ATM based VDSL communication system comprising:

an ATM network connected to the alarm service provider;

a host digital terminal connected to the ATM network by an ATM permanent virtual circuit, the ATM permanent virtual circuit being supported on a fiber optics link, the host digital terminal and the alarm service provider

communicating alarm signals on the ATM permanent virtual circuit through the ATM network;

an optical network unit connected to the host digital terminal by the fiber optics link;

a customer provided equipment (CPE) data device connected through the optical network unit to the host digital terminal by a VDSL permanent virtual circuit, the VDSL permanent virtual circuit being supported on the fiber optics link between the host digital terminal and the optical network unit and a twisted pair link between the optical network unit and the CPE data device, the CPE data device and the host digital terminal communicating the alarm signals on the VDSL permanent virtual circuit; and

a subscriber terminal unit connected to the CPE data device for communicating the alarm signals with the CPE data device;

wherein the host digital terminal connects the ATM permanent virtual circuit and the VDSL permanent virtual circuit to communicate the alarm signals between the alarm service provider and the subscriber terminal unit.

2. The ATM based VDSL communication system of claim 1 wherein:

the alarm signals include data signals.

3. The ATM based VDSL communication system of claim 2 wherein:

the alarm service provider transmits a polling data signal to the subscriber terminal unit and the alarm service provider detects an alarm condition if the subscriber terminal unit fails to transmit an acknowledgment data signal to the alarm service provider in response to the polling data signal.

4. The ATM based VDSL communication system of claim 3 wherein:

the subscriber terminal unit transmits an acknowledgment data signal to the alarm service provider in response to a polling data signal if an alarm condition is not present.

5. The ATM based VDSL communication system of claim 1 wherein:

the alarm signals include video signals.

6. The ATM based VDSL communication system of claim 5 wherein:

the subscriber terminal unit transmits video signals to the alarm service provider.

7. The ATM based VDSL communication system of claim 1 wherein:

wherein the ATM permanent virtual circuit is selected by the host digital terminal from a plurality of ATM permanent virtual circuits for connection to the VDSL permanent virtual circuit, wherein the host digital terminal switches between a first ATM permanent virtual circuit for communicating data alarm signals between the alarm service provider and the subscriber terminal unit and a second ATM permanent virtual circuit for communicating video alarm signals between the alarm service provider and the subscriber terminal unit.

8. The ATM based VDSL communication system of claim 7 wherein:

the host digital terminal switches between the first and second ATM permanent virtual circuits in response to a meta signaling data signal from the subscriber terminal unit.

9. The ATM based VDSL communication system of claim 1 wherein:

a 10baseT port connects the CPE data device and the subscriber terminal unit.

10. An asynchronous transfer mode (ATM) based very-high-bit-rate digital subscriber line (VDSL) communication system for providing alarm services between an alarm service provider and a subscriber, the ATM based VDSL communication system comprising:

an ATM network connected to the alarm service provider;

a host digital terminal connected to the ATM network by an ATM permanent virtual circuit, the ATM permanent virtual circuit being supported on a fiber optics link, the host digital terminal and the alarm service provider communicating alarm signals on the ATM permanent virtual circuit through the ATM network;

an optical network unit connected to the host digital terminal by the fiber optics link;

a customer provided equipment (CPE) data device connected through the optical network unit to the host digital terminal by a VDSL permanent virtual circuit, the VDSL permanent virtual circuit being supported on the fiber optics link between the host digital terminal and the optical network unit and a twisted pair link between the optical network unit and the CPE data device, the CPE data device and the host digital terminal communicating the alarm signals on the VDSL permanent virtual circuit; and

a subscriber terminal unit connected to the CPE data device for communicating the alarm signals with the CPE data device;

wherein the host digital terminal connects the ATM permanent virtual circuit and the VDSL permanent virtual circuit to communicate the alarm signals between the alarm service provider and the subscriber terminal unit, wherein the ATM permanent virtual circuit is selected by the host digital terminal from a plurality of ATM permanent virtual circuits for connection to the VDSL permanent virtual circuit, wherein the host digital terminal switches between a first ATM permanent virtual circuit for communicating data alarm signals between the alarm service provider and the subscriber terminal unit and a second ATM permanent virtual circuit for communicating video alarm signals between the alarm service provider and the subscriber terminal unit.

11. The ATM based VDSL communication system of claim 10 wherein:

the host digital terminal switches between the first and second ATM permanent virtual circuits in response to a meta signaling data signal from the subscriber terminal unit.

12. An asynchronous transfer mode (ATM) based very-high-bit-rate digital subscriber line (VDSL) communication system for providing alarm services between an alarm service provider and a subscriber, the ATM based VDSL communication system comprising:

an ATM network connected to the alarm service provider and an information service provider;

a host digital terminal connected to the ATM network by first and second ATM permanent virtual circuits, the first and second ATM permanent virtual circuits being supported on a fiber optics link, the host digital terminal and the alarm service provider communicating alarm signals on the first ATM permanent virtual circuit through the ATM network, the host digital terminal and

the information service provider communicating information signals on the second ATM permanent virtual circuit through the ATM network;

an optical network unit connected to the host digital terminal by the fiber optics link;

a customer provided equipment (CPE) data device connected through the optical network unit to the host digital terminal by first and second VDSL permanent virtual circuits, the first and second VDSL permanent virtual circuits being supported on the fiber optics link between the host digital terminal and the optical network unit and a twisted pair link between the optical network unit and the CPE data device, the CPE data device and the host digital terminal communicating the alarm signals on the first and second VDSL permanent virtual circuits;

a subscriber alarm terminal unit connected to the CPE data device by a first 10baseT port for communicating the alarm signals with the CPE data device; and

a subscriber information terminal unit connected to the CPE data device by a second 10baseT port for communicating the information signals with the CPE data device;

wherein the host digital terminal connects the first ATM permanent virtual circuit and the first VDSL permanent virtual circuit to communicate the alarm signals between the alarm service provider and the subscriber alarm terminal unit and connects the second ATM permanent virtual circuit and the second VDSL permanent virtual circuit to communicate the information signals between the information service provider and the subscriber information terminal unit.

13. The ATM based VDSL communication system of claim 12 wherein:

the alarm signals include data signals.

14. The ATM based VDSL communication system of claim 13 wherein:

the alarm service provider transmits a polling data signal to the subscriber alarm terminal unit and the alarm service provider detects an alarm condition if the subscriber alarm terminal unit fails to transmit an acknowledgment data signal to the alarm service provider in response to the polling data signal.

15. The ATM based VDSL communication system of claim 14 wherein:

the subscriber alarm terminal unit transmits an acknowledgment data signal to the alarm service provider in response to a polling data signal if an alarm condition is not present.

16. The ATM based VDSL communication system of claim 12 wherein:

the alarm signal include video signals.

17. The ATM based VDSL communication system of claim 16 wherein:

the subscriber alarm terminal unit transmits video signals to the alarm service provider.

18. The ATM based VDSL communication system of claim 12 wherein:

wherein the first ATM permanent virtual circuit is selected by the host digital terminal from a pool of ATM permanent virtual circuits associated with the alarm service provider for connection to the first VDSL permanent virtual circuit, wherein the host digital terminal switches between a first ATM permanent virtual circuit in the pool for communicating data alarm signals between the alarm service provider and the subscriber alarm terminal unit and a second ATM permanent virtual circuit in the pool for communicating video alarm signals between the alarm service provider and the subscriber alarm terminal unit.

19. The ATM based VDSL communication system of claim 18 wherein:

the host digital terminal switches between the first and second ATM permanent virtual circuits in the pool in response to a meta signaling data signal from the subscriber terminal unit.

20. The ATM based VDSL communication system of claim 12 further comprising:

a telephone line connecting the subscriber alarm terminal unit to the twisted pair link for providing a link to the central office in case the CPE data device is powered off.

* * * * *

US006181711B1

(12) **United States Patent**
Zhang et al.

(10) **Patent No.: US 6,181,711 B1**
(45) **Date of Patent: Jan. 30, 2001**

(54) **SYSTEM AND METHOD FOR TRANSPORTING A COMPRESSED VIDEO AND DATA BIT STREAM OVER A COMMUNICATION CHANNEL**

(75) Inventors: **Ji Zhang**, San Jose; **Wen H. Chen**, Sunnyvale; **Fang Wu**, San Jose, all of CA (US)

(73) Assignee: **Cisco Systems, Inc.**, San Jose, CA (US)

(*) Notice: Under 35 U.S.C. 154(b), the term of this patent shall be extended for 0 days.

(21) Appl. No.: **08/947,480**

(22) Filed: **Oct. 10, 1997**

Related U.S. Application Data

(60) Provisional application No. 60/051,109, filed on Jun. 26, 1997.

(51) **Int. Cl.**^{7} **H04J 3/16**
(52) **U.S. Cl.** **370/468**; 370/538
(58) **Field of Search** 370/465, 468, 370/545, 522, 537, 538, 203, 210, 484

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,493,456		2/1996	Augenbraum et al.	360/64
5,570,197		10/1996	Boon	386/46
5,751,701	*	5/1998	Langberg et al.	370/281
5,754,235	*	5/1998	Urano et al.	348/405
5,812,786	*	9/1998	Seazholtz et al.	709/233
6,026,097	*	2/2000	Voois et al.	370/468

OTHER PUBLICATIONS

Information Technology—Generic Coding of Moving Pictures and Associated Audio, ISO/IEC 1–13818–1, Nov. 13, 1994.
"Network and Customer Installation Interfaces—Asymmetric Digital Subscriber Line (ADSL) Metallic Interface," American National Standards Institute, ANSI T1. 413–1995.
The ATM Forum Technical Committee User–Network Interface Specification, Version 3.1 (UNI 3.1), Aug. 18, 1995.

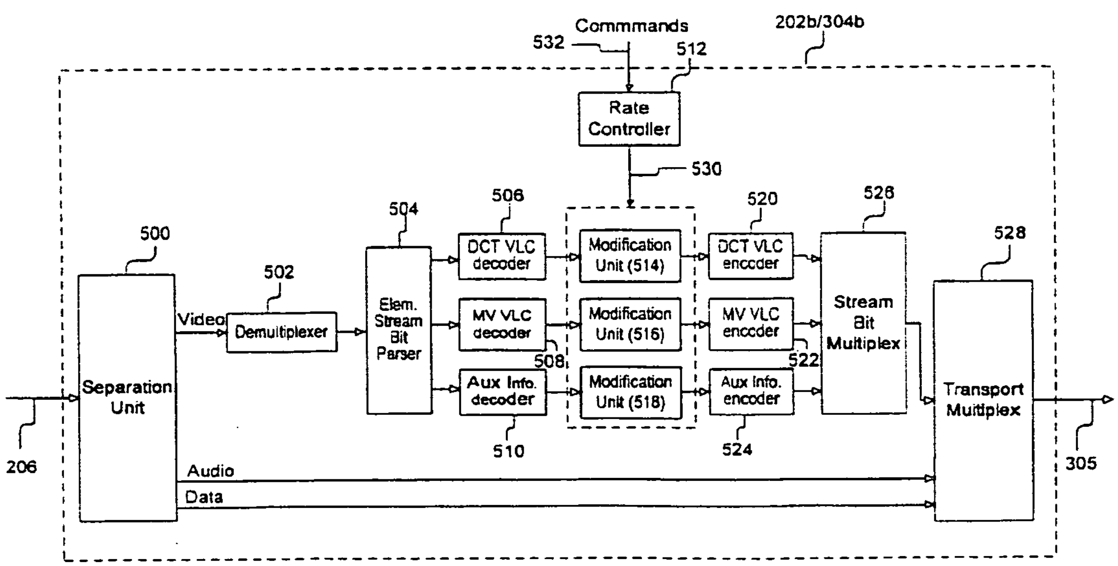
* cited by examiner

Primary Examiner—Joseph L. Felber
(74) *Attorney, Agent, or Firm*—Beyer Weaver & Thomas, LLP

(57) **ABSTRACT**

Digitally compressed video/audio bit streams, when transmitted over digital communication channels such as digital subscriber loop (DSL) access networks, ATM networks, satellite, or wireless digital transmission facilities, can be corrupted due to lack of sufficient channel bandwidth. This invention describes schemes to ensure lossless transmission of bit streams containing pre-compressed video signals within the communication channels. The schemes herein comprises a rate conversion system that converts the bit rate of a pre-compressed video bit stream from one bit rate to another, and that is integrated with a digital communication channel, and a means to convey the maximum channel transmission rate to the rate conversion system to allow satisfactory transmission of the bit stream from the input of the rate converter through the transmission facility.

37 Claims, 16 Drawing Sheets



05/03/2002, EAST Version: 1.03.0002

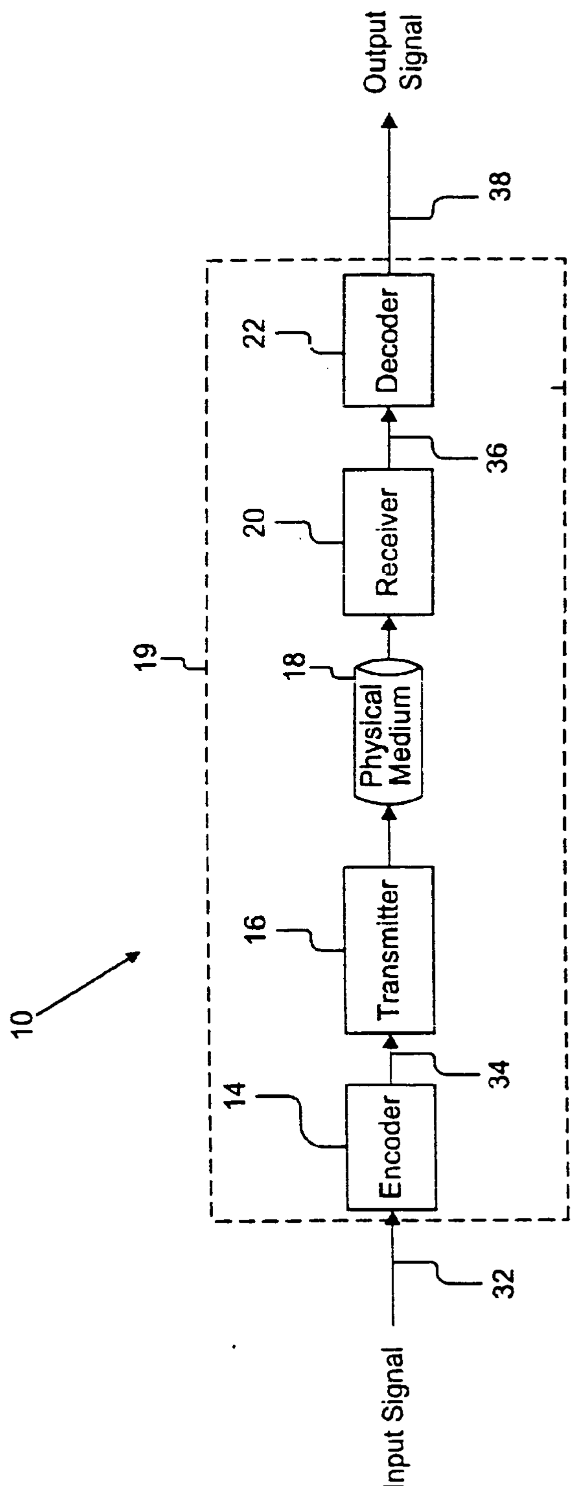


Figure 1A
(Prior Art)

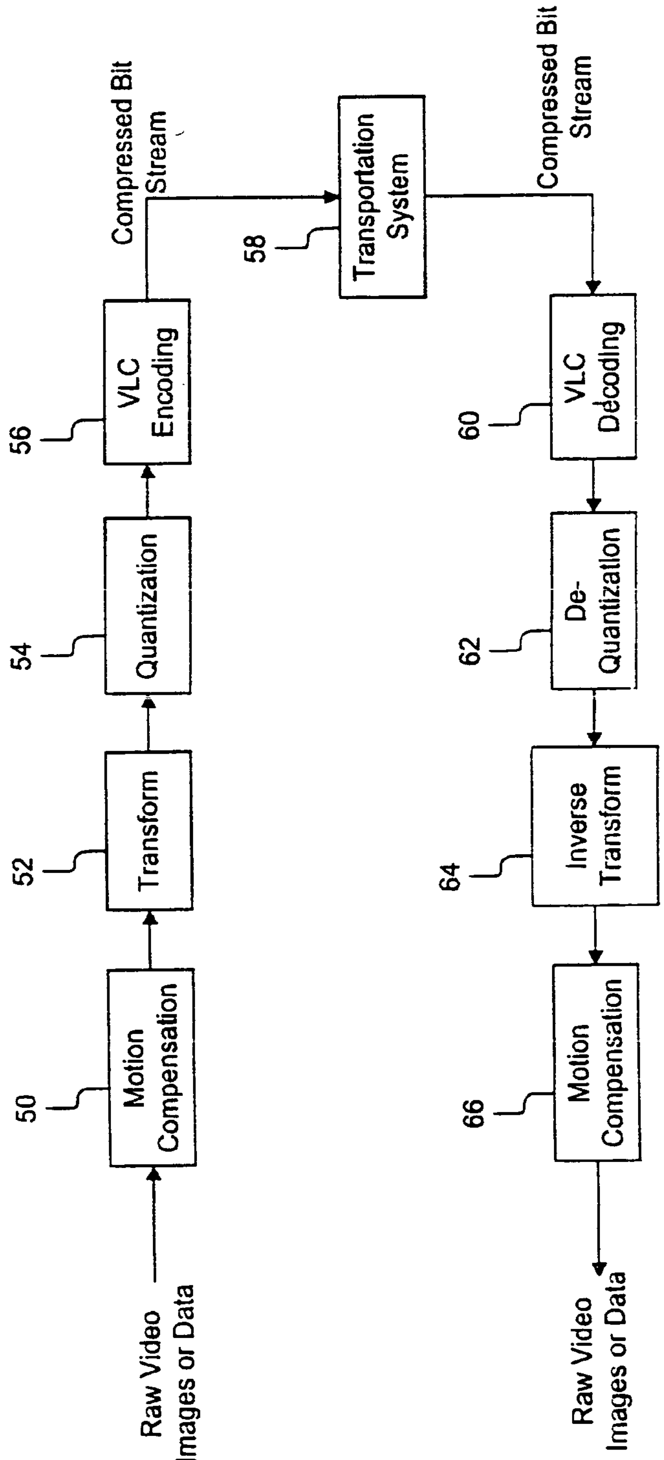


Figure 1B (Prior Art)

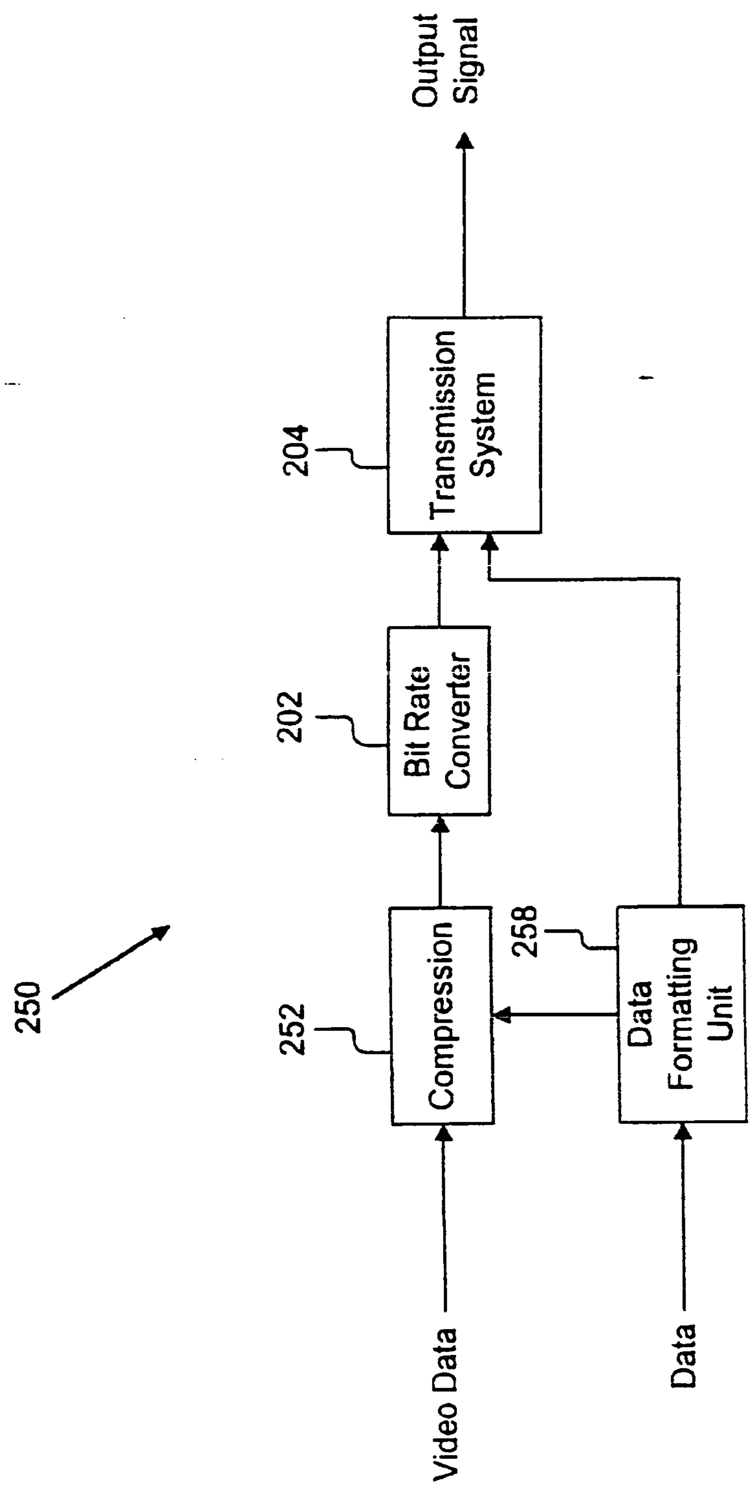

250
Video Data
Data
252
Compression
258
Data Formatting Unit
202
Bit Rate Converter
204
Transmission System
Output Signal

Figure 2A

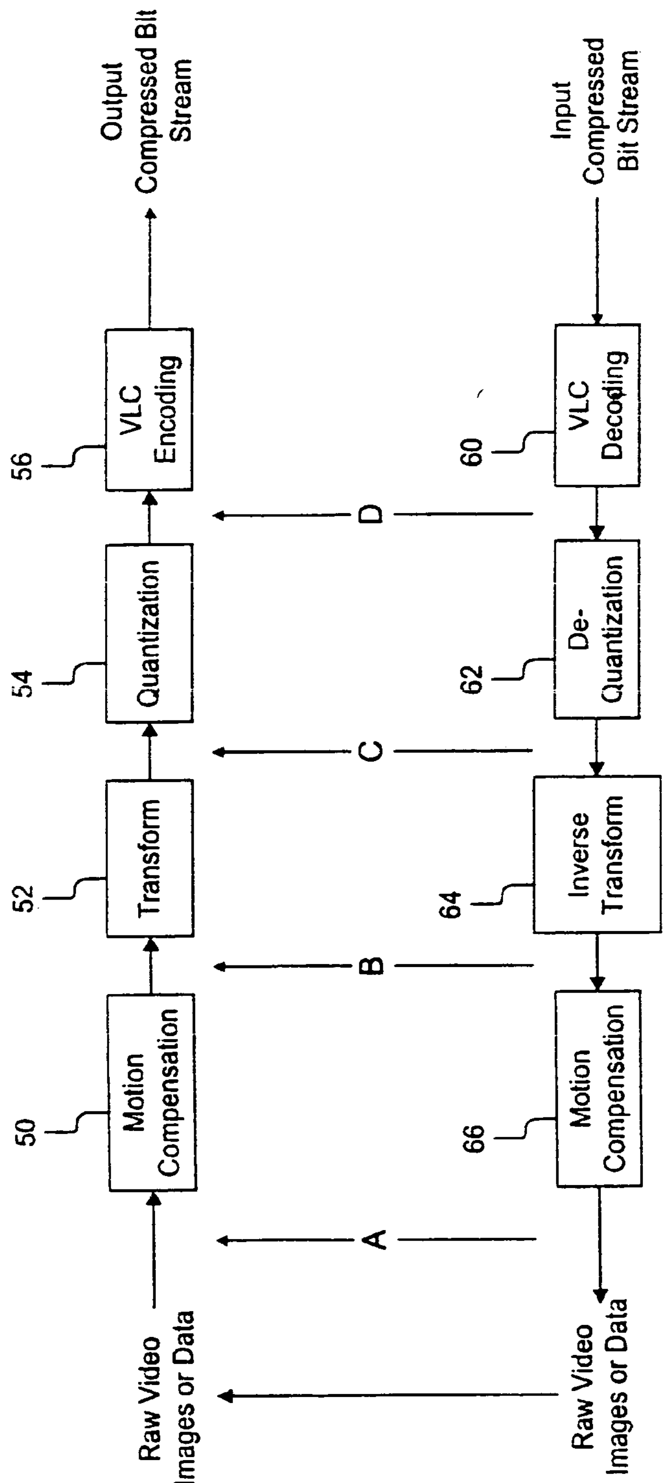
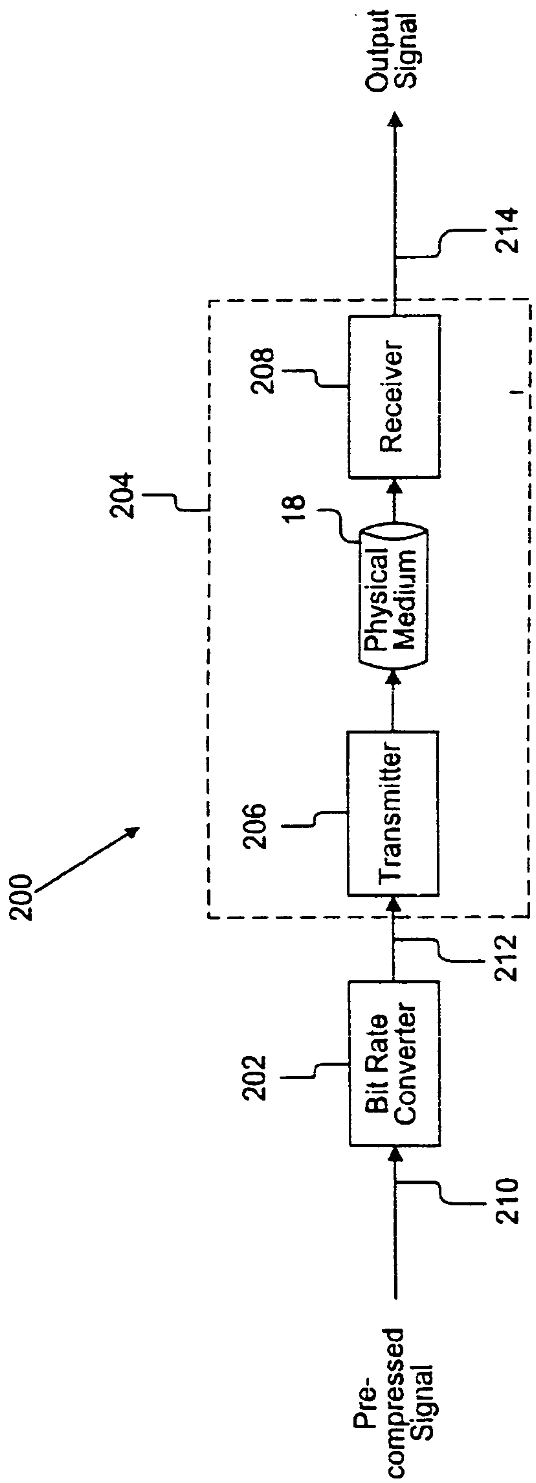

Raw Video Images or Data
Motion Compensation
50
Transform
52
Quantization
54
VLC Encoding
56
Output Compressed Bit Stream
A
B
C
D
Input Compressed Bit Stream
VLC Decoding
60
De-Quantization
62
Inverse Transform
64
Motion Compensation
66
Raw Video Images or Data

Figure 2B



Output Signal
214
208
Receiver
204
18
Physical Medium
206
Transmitter
200
212
202
Bit Rate Converter
210
Pre-compressed Signal

Figure 2C

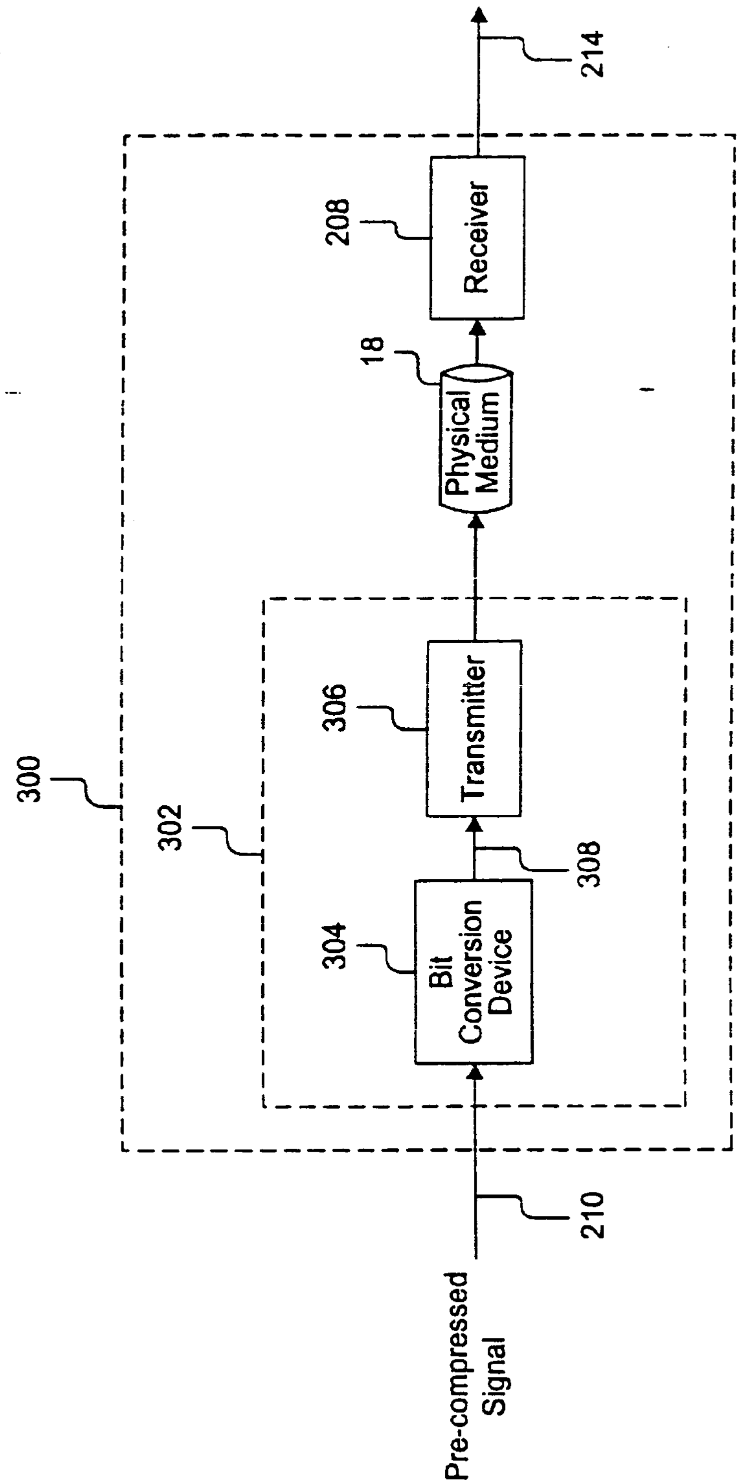

Pre-compressed Signal
210
300
302
304
Bit Conversion Device
308
306
Transmitter
18
Physical Medium
208
Receiver
214

Figure 3

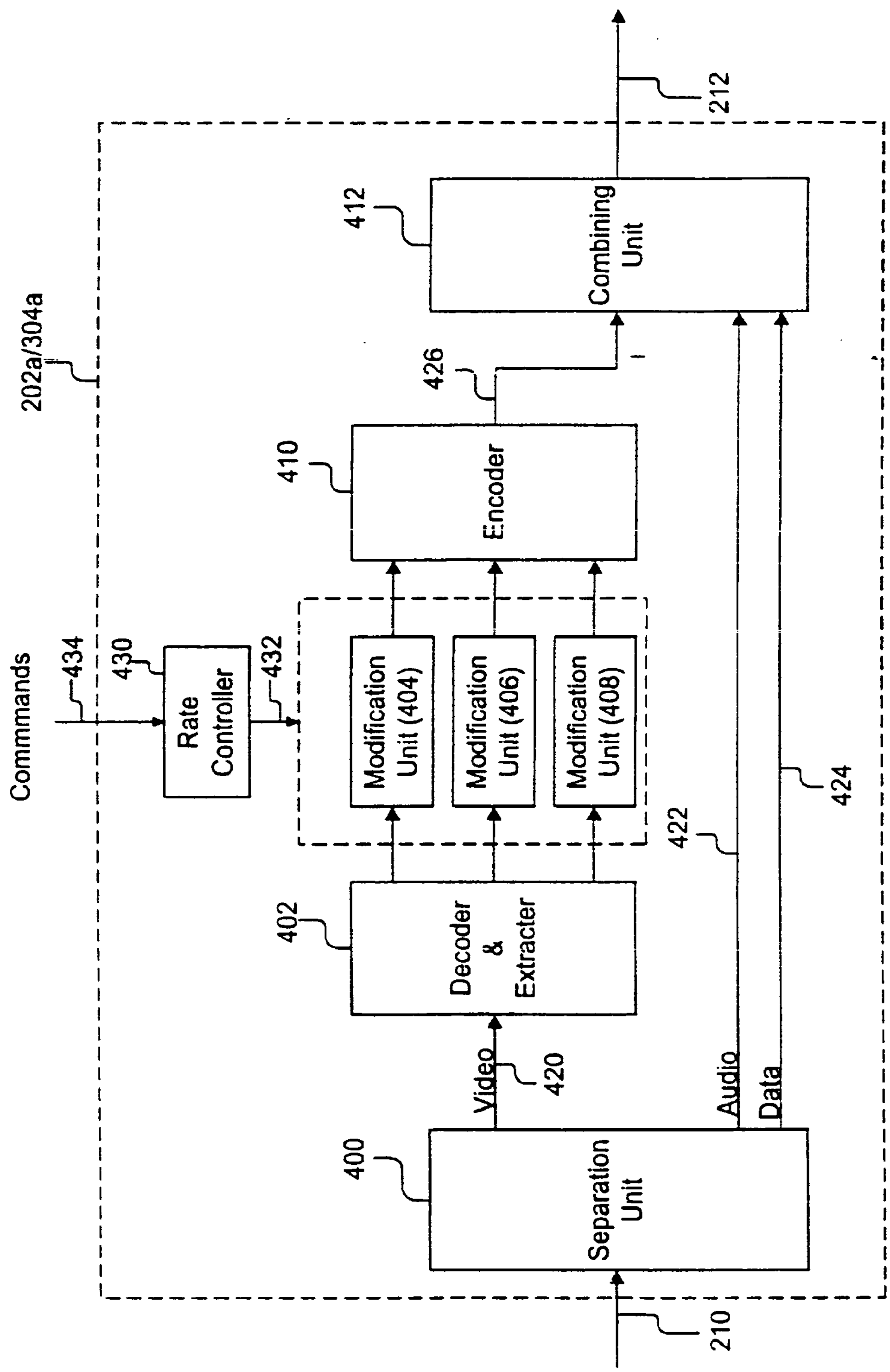
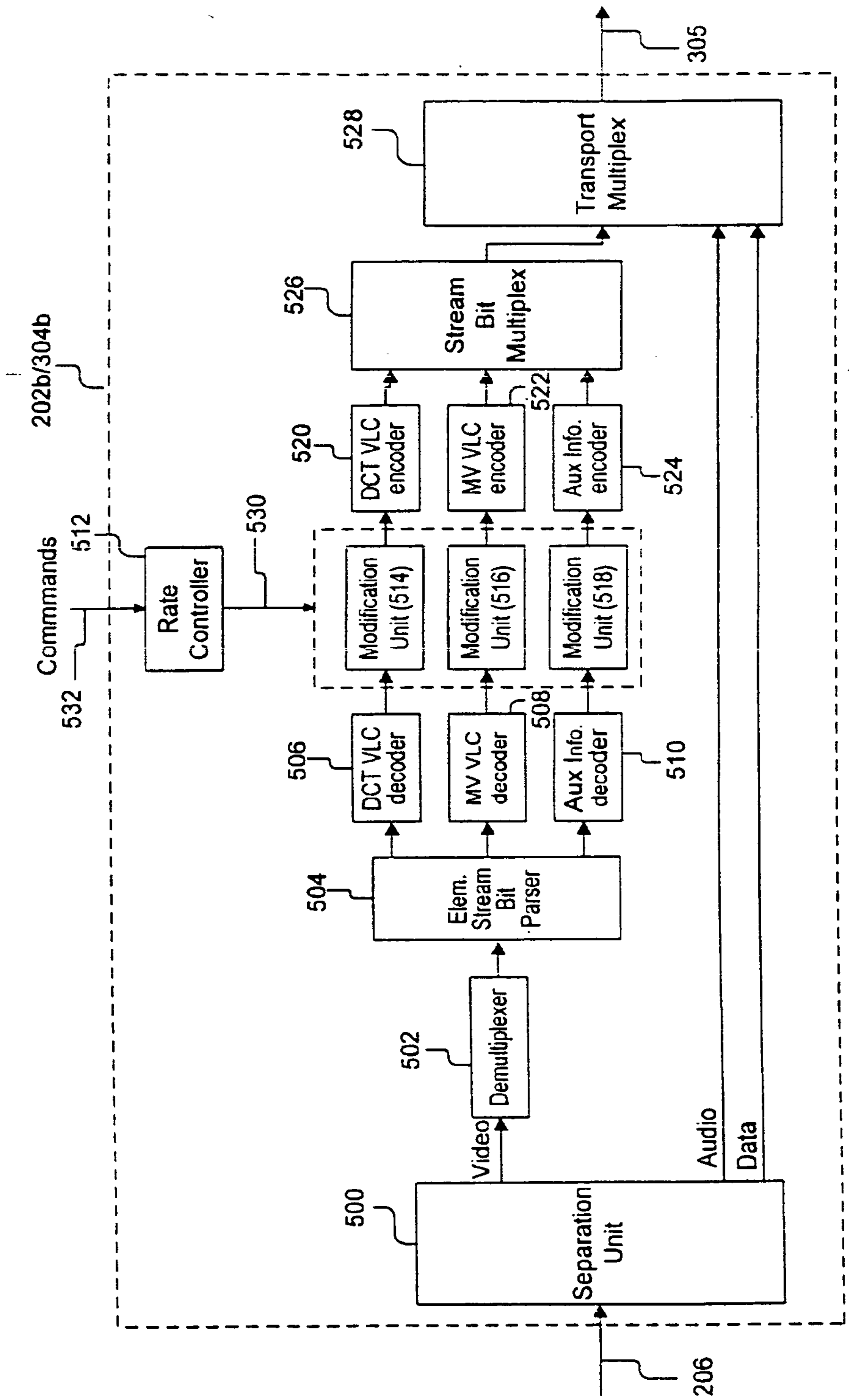

202a/304a
Commands
434
430
Rate Controller
432
Modification Unit (404)
Modification Unit (406)
Modification Unit (408)
410
Encoder
426
412
Combining Unit
212
400
Separation Unit
Video
420
402
Decoder & Extracter
Audio
Data
422
424
210

Figure 4



202b/304b
305
528
Transport Multiplex
526
Stream Bit Multiplex
520
DCT VLC encoder
MV VLC encoder
522
Aux Info. encoder
524
512
Rate Controller
Commands
532
530
Modification Unit (514)
Modification Unit (516)
Modification Unit (518)
506
DCT VLC decoder
MV VLC decoder
508
Aux Info. decoder
510
504
Elem. Stream Bit Parser
502
Demultiplexer
Video
Audio
Data
500
Separation Unit
206

Figure 5

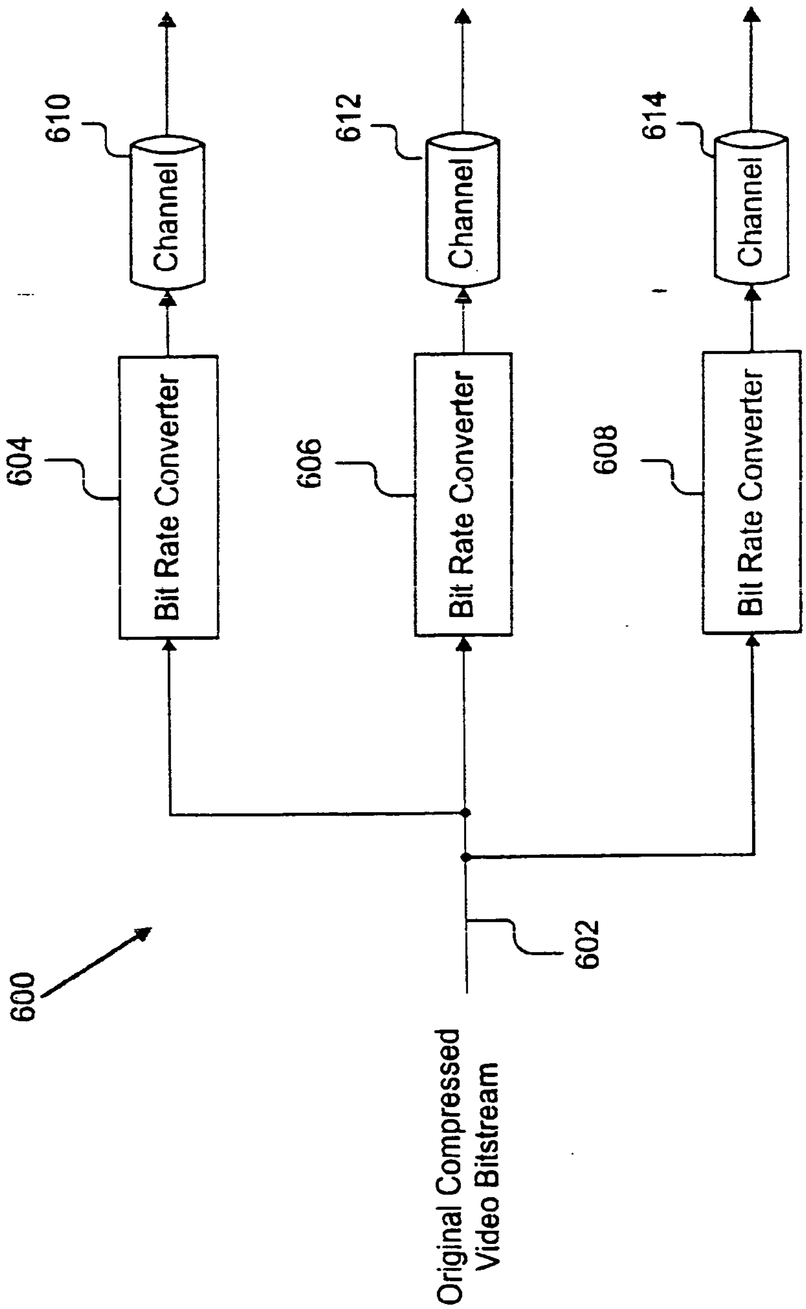

600
Original Compressed
Video Bitstream
602
604
Bit Rate Converter
606
Bit Rate Converter
608
Bit Rate Converter
610
Channel
612
Channel
614
Channel

Figure 6

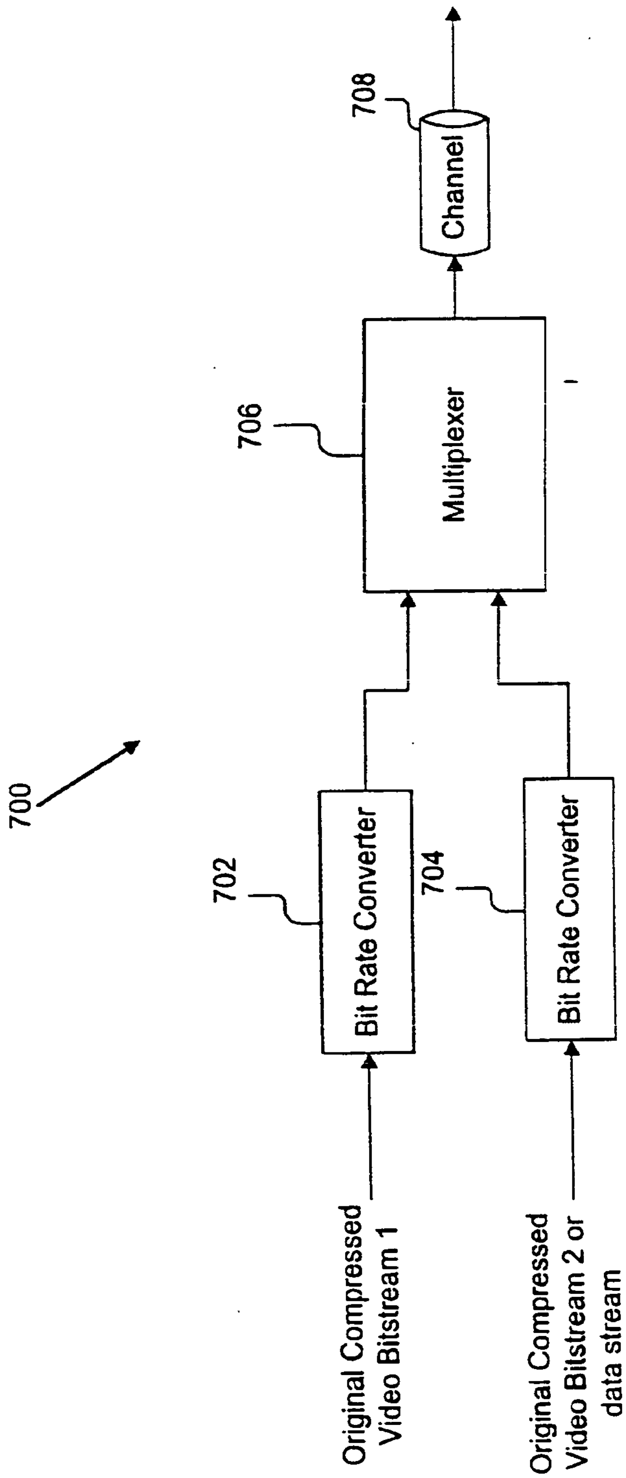
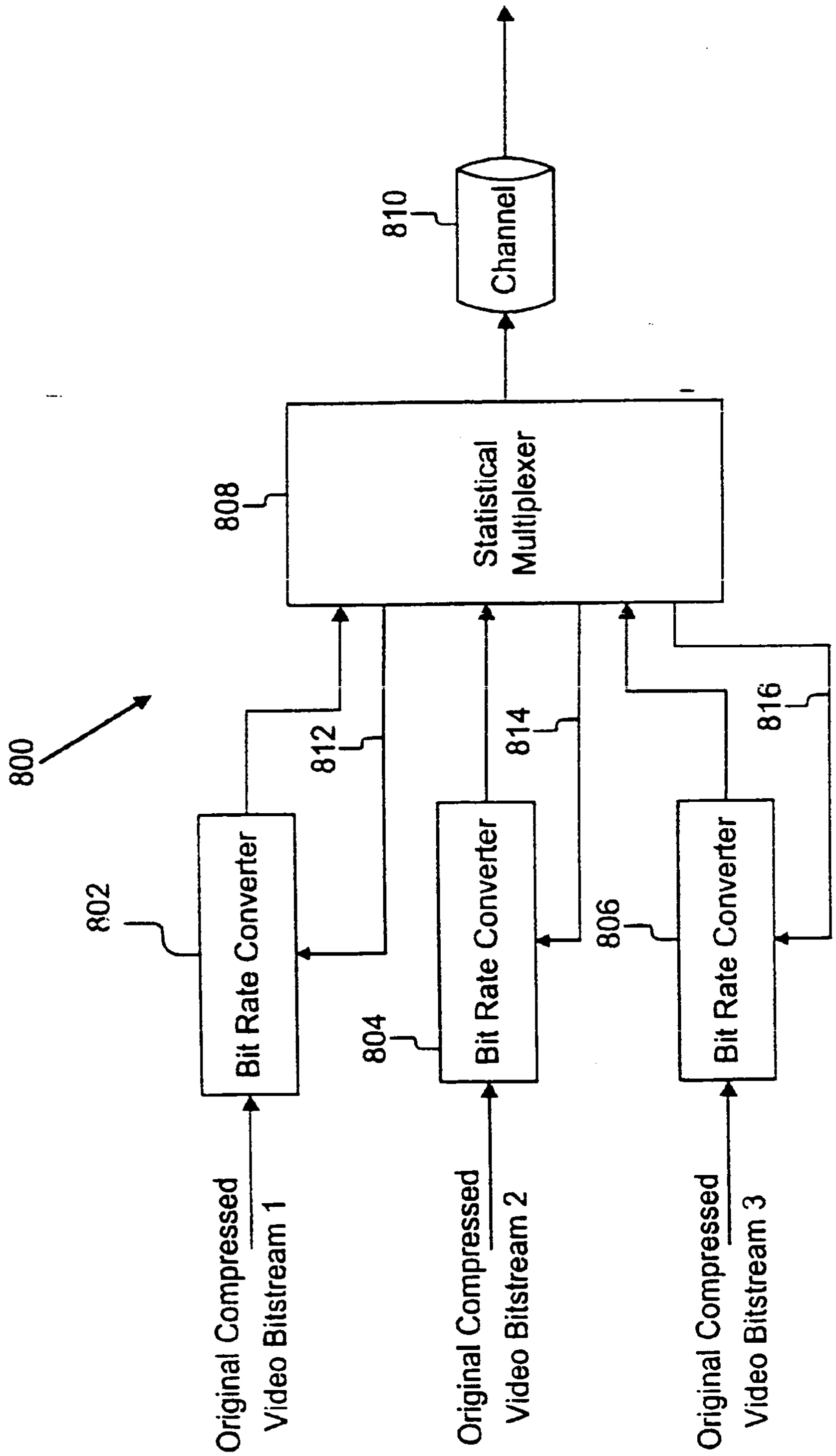

700
Original Compressed Video Bitstream 1
Original Compressed Video Bitstream 2 or data stream
702
Bit Rate Converter
704
Bit Rate Converter
706
Multiplexer
708
Channel

Figure 7



800
Original Compressed Video Bitstream 1
Original Compressed Video Bitstream 2
Original Compressed Video Bitstream 3
802
804
806
Bit Rate Converter
Bit Rate Converter
Bit Rate Converter
812
814
816
808
Statistical Multiplexer
810
Channel

Figure 8

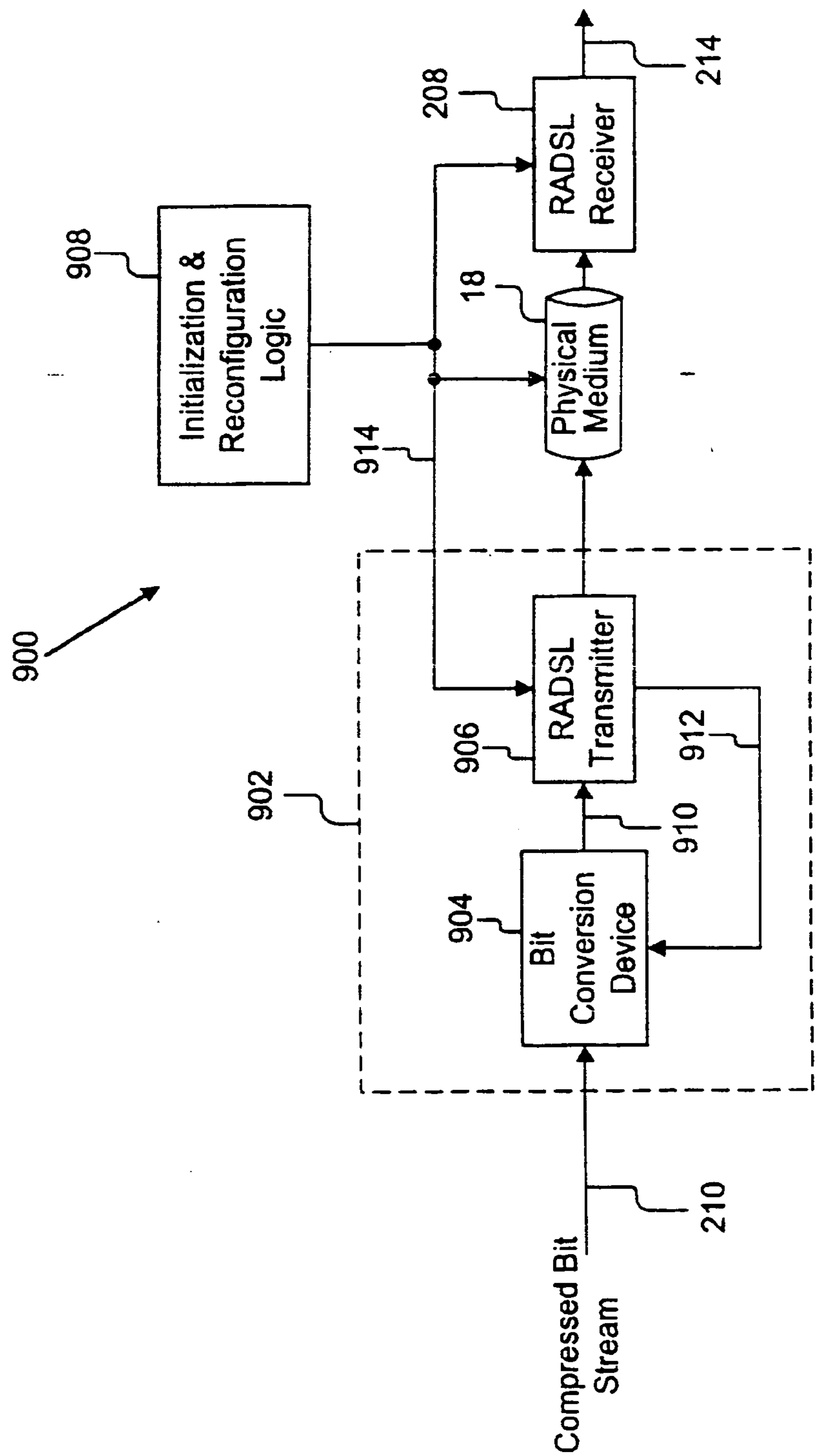

900
902
904
Bit
Conversion
Device
906
RADSL
Transmitter
908
Initialization &
Reconfiguration
Logic
910
912
914
18
Physical
Medium
208
RADSL
Receiver
214
210
Compressed Bit
Stream

Figure 9

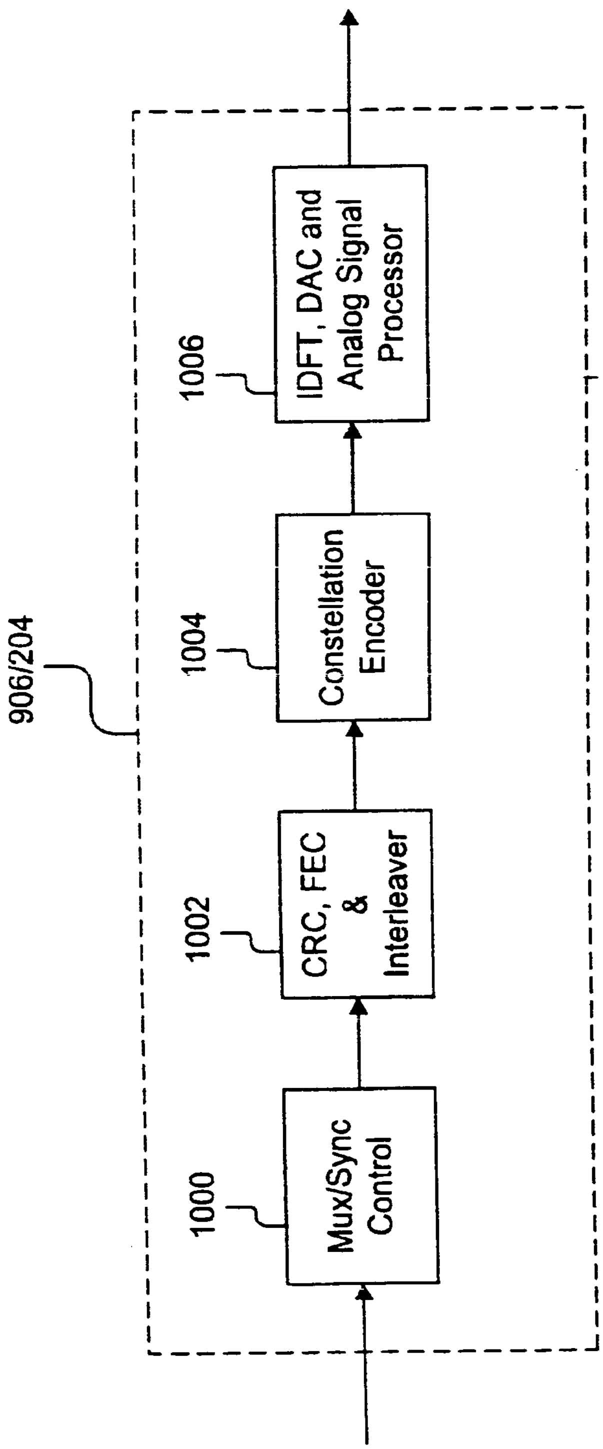

906/204
1000
Mux/Sync Control
1002
CRC, FEC & Interleaver
1004
Constellation Encoder
1006
IDFT, DAC and Analog Signal Processor

Figure 10

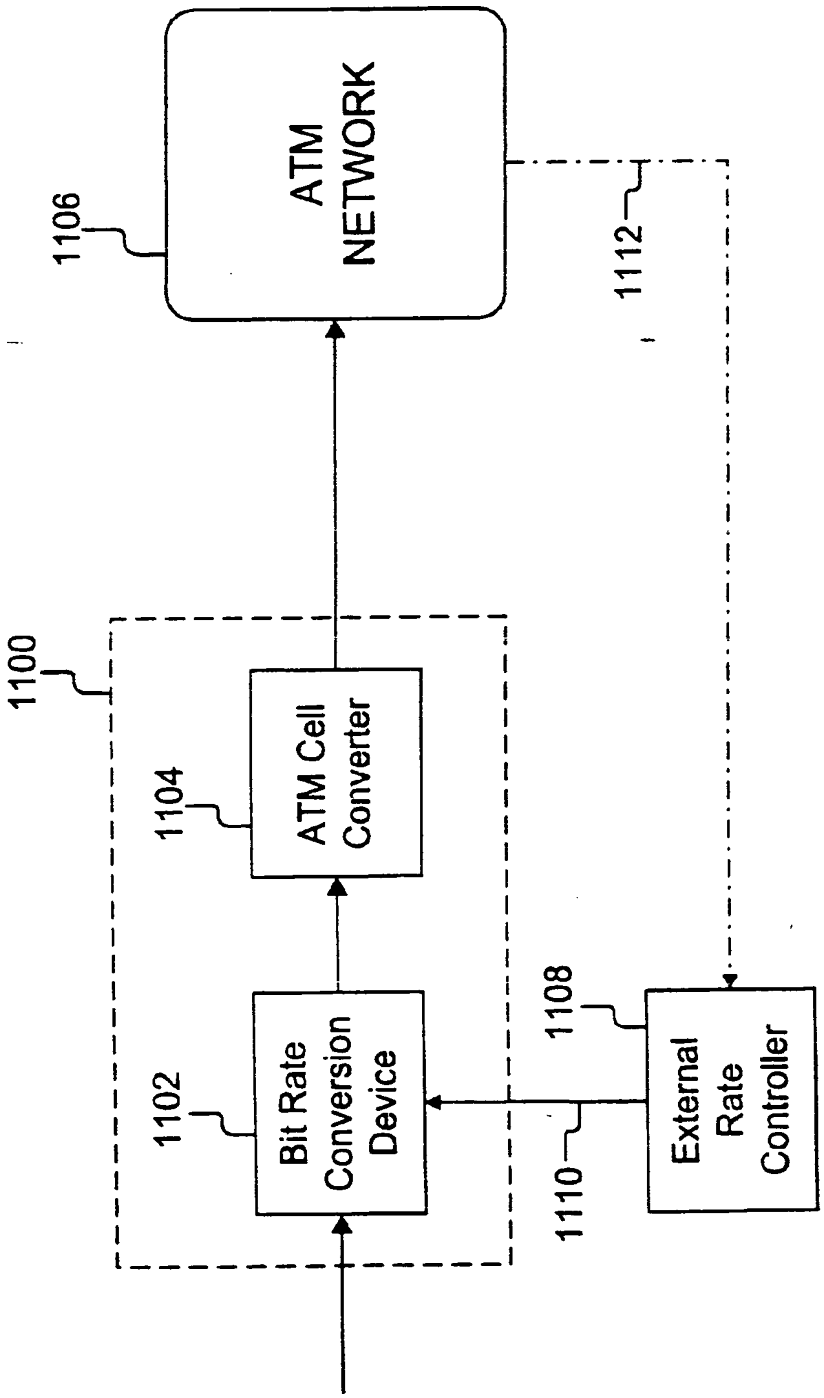

ATM NETWORK
1106
1112
1100
ATM Cell Converter
1104
Bit Rate Conversion Device
1102
1108
External Rate Controller
1110

Figure 11

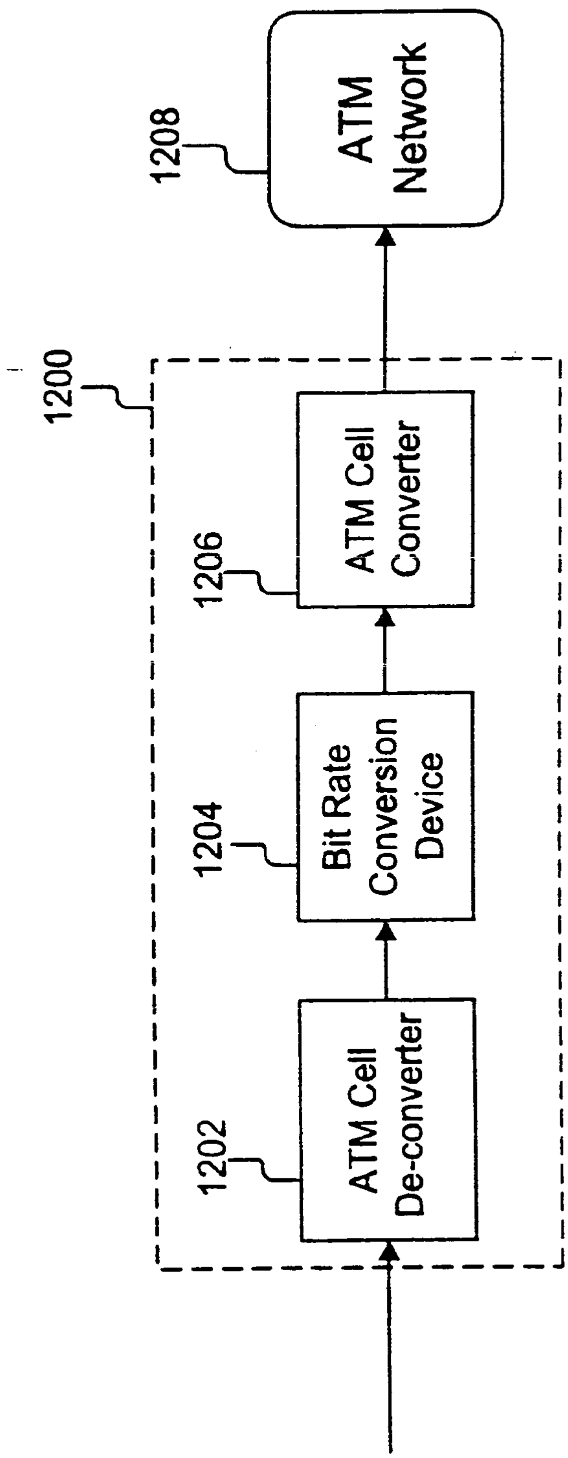

1208
ATM Network
1200
1206
ATM Cell Converter
1204
Bit Rate Conversion Device
1202
ATM Cell De-converter

Figure 12

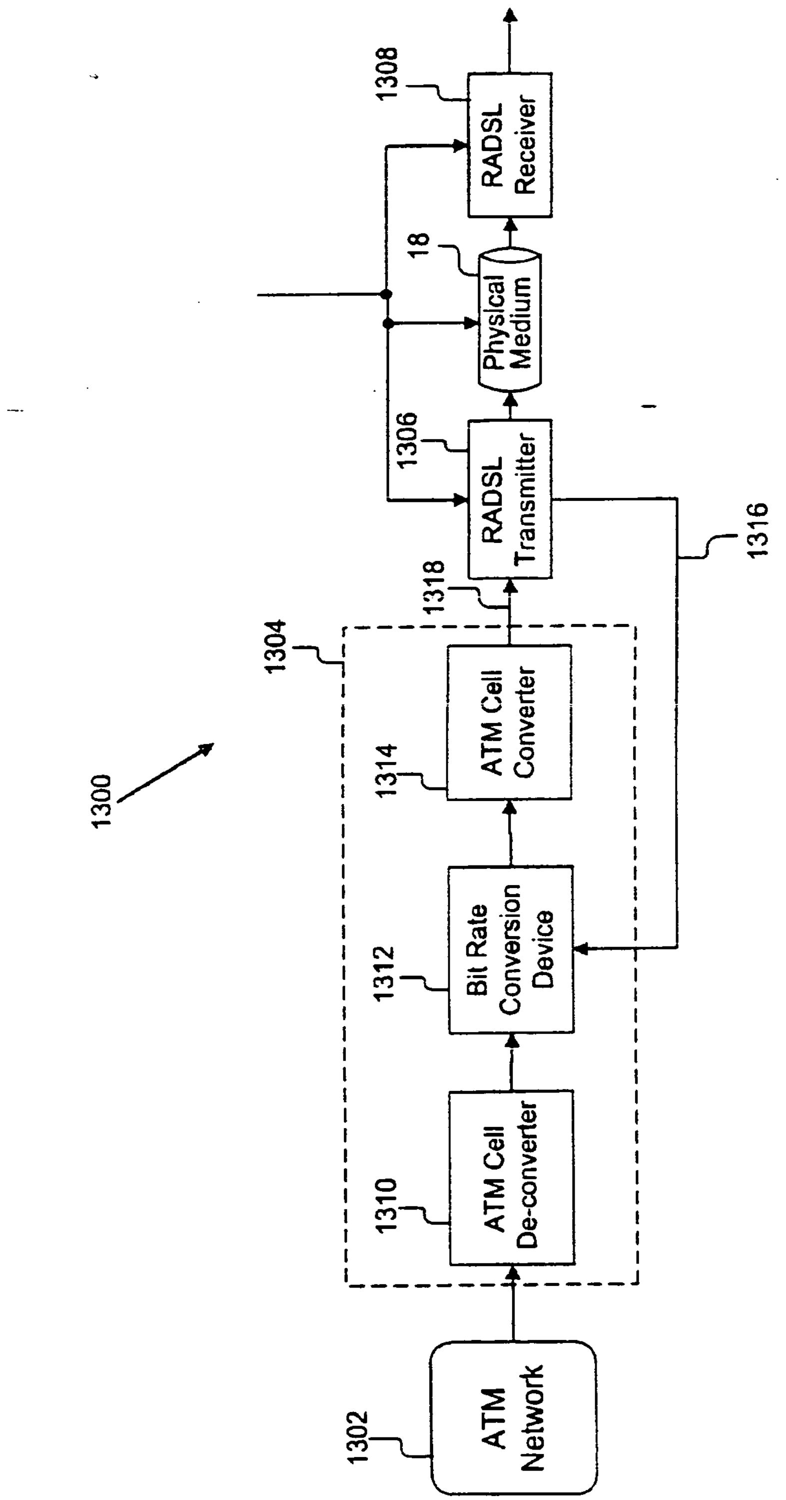

1300
1302
ATM Network
1304
1310
ATM Cell De-converter
1312
Bit Rate Conversion Device
1314
ATM Cell Converter
1318
1306
RADSL Transmitter
1316
18
Physical Medium
1308
RADSL Receiver

Figure 13

SYSTEM AND METHOD FOR TRANSPORTING A COMPRESSED VIDEO AND DATA BIT STREAM OVER A COMMUNICATION CHANNEL

This application claims benefit of provisional application Ser. No. 06/051,109, filed Jun. 26, 1997.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to communication channels and systems for transmitting data. In particular, the present invention relates to a system and method for transmitting compressed digital video signals over a communication channel. Still more particularly, the present invention relates to a system and method for transmitting compressed digital video signals over digital subscriber loop (DSL) access networks and asynchronous transfer mode (ATM) networks.

2. Description of the Background Art

There are presently a variety of different communication channels for transmitting or transporting video data. For example, communication channels such as digital subscriber loop (DSL) access networks, ATM networks, satellite, or wireless digital transmission facilities are all well known. In fact, many standards have been developed for transmitting data on the communication channels. The present invention relates to such communication channels, and for the purposes of the present application a channel is defined broadly as a connection facility to convey properly formatted digital information from one point to another. A channel includes some or all of the following elements: 1) physical devices that generate and receive the signals (modulator/demodulator); 2) physical medium that carries the actual signals; 3) mathematical schemes used to encode and decode the signals; 4) proper communication protocols used to establish, maintain and manage the connection created by the channel. The concept of a channel includes but is not limited to a physical channel, but also logical connections established on top of different network protocols, such as xDSL, ATM, TCP/IP, wireless, HFC, coaxial cable, etc.

The channel is used to transport a bit stream, or a continuous sequence of binary bits used to digitally represent compressed video, audio or data. The bit rate is the number of bits per second that the channel is able to transport. The bit error rate is the statistical ratio between the number of bits in error due to transmission and the total number of bits transmitted. The channel capacity is the maximum bit rate at which a given channel can convey digital information with a bit error rate no more than a given value. And finally, a multiplex is a scheme used to combine bit stream representations of different signals, such as audio, video, or data, into a single bit stream representation.

One problem with existing communication channels is their ability to handle the transportation of video data. Video data is much larger than many other types of data, and therefore, requires much more bandwidth from the communication channels. Since transmission of video data with existing communication channels would require excessive amounts of time, compression is an approach that has been used to make digital video images more transportable.

Digital video compression schemes allow digitized video frames to be represented digitally in much more efficient manner. Compression of digital video makes it practical to transmit the compressed signal by digital channels at a fraction of the bandwidth required to transmit the original

signal without compression. International standards have been created on video compression schemes. These include MPEG-1, MPEG-2, H.261, H.262, H.263, etc. These standardized compression schemes mostly rely on several key algorithm schemes: motion compensated transform coding (for example, DCT transforms or wavelet/sub-band transforms), quantization of the transform coefficients, and variable length encoding (VLC). The motion compensated encoding removes the temporally redundant information inherent in video sequences. The transform coding enables orthogonal spatial frequency representation of spatial domain video signals. Quantization of the transformed coefficients reduces the number of levels required to represent a given digitized video sample and is the major factor in bit usage reduction in the compression process. The other factor contributing to the compression is the use of variable length coding (VLC) so that most frequently used symbols are represented by the shortest code word. In general, the number of bits used to represent a given image determines the quality of the decoded picture. The more bits used to represent a given image, the better the image quality. The system that is used to compress digitized video sequence using the above described schemes is called an encoder or encoding system.

In the prior art compression schemes, the quantization scheme is lossy, or irreversible process. Specifically, it results in loss of video textural information that cannot be recovered by further processing at a later stage. In addition, the quantization process has direct effect on the resulting bit usage and decoded video quality of the compressed bit stream. The schemes at which the quantization parameters are adjusted control the resulting bit rate of the compressed bit stream. The resulting bit stream can have either constant bit rate, CBR, or variable bit rate, VBR. CBR compressed bit stream can be transmitted over channel delivers digital information at a constant bit rate.

A compressed video bit stream generally is intended for real-time decoded playback at a different time or location. The decoded real-time playback must be done at 30 frames per second for NTSC standard video and 25 frames per second for PAL standard video. This implies that all of the information required to represent a digital picture must be delivered to the destination in time for decoding and display in timely manner. Therefore, this requires that the channel must be capable of making such delivery. From a different perspective, the transmission channel imposes bit rate constraint on the compressed bit stream. In general, the quantization in the encoding process is adjusted so that the resulting bit rate can be accepted by the transmission channel.

Because both temporal and spatial redundancies are removed by the compression schemes and because of variable length encoding, the resulting bit stream is much more sensitive to bit errors or bit losses in the transmission process than if the uncompressed video is transmitted. In other words, minor bit error or loss of data in compressed bit stream typically results in major loss of video quality or even complete shutdown of operation of the digital receiver/decoder.

Further, a real-time multimedia bit stream is highly sensitive to delays. A compressed video bit stream, when transmitted under excessive and jittery delays, will cause the real-time decoder buffer to under flow or overflow, causing the decoded video sequence to be jerky, or causing the audio video signals out of synchronization. Another consequence of the real-time nature of compressed video decoding is that lost compressed data will not be re-transmitted.

One particular communication channel that is becoming increasingly common is Asynchronous Transfer Mode (ATM) networks. ATM networks are based on the ATM transport protocol which can be used to transport data or multimedia bit stream with pre-specified quality of service. Unlike the xDSL standard, ATM protocols specifies how data is first packetized into fixed sized data units, called cells. It also specifies how such a cell stream can be multiplexed, de-multiplexed, switched and routed between different locations to support end-to-end connections at given bit rate and/or quality of service (QOS). In ATM networks, data bit stream to be transported are first converted into fixed sized ATM cells, each cell has a 5 byte header and up to 48 bytes of payload. Of particular interests to our invention is the capability of ATM networks to carry MPEG transport streams.

In ATM networks, connections can be established with pre-determined grade of QOS. Conditions of network utilization, along with call admission control sometimes may prevent a new connection from being established at the given bit rate or given quality of service. In such cases, the requested connection may either have to be rejected or a new set of admissible connection parameters have to be negotiated between the network service provider and the user requesting the connection.

ATM networks can be used to carry either constant bit rate (CBR) or variable bit rate (VBR) bit stream. The bit stream may be compressed bit stream or data. In either case, an agreement must be made between the user requesting the connection and the network service provider. The connection agreement includes the bit rate profile of the bit stream and quality of service. If such an agreement cannot be reached, either the connection must be rejected, or the bit rate profile must be modified, or the mismatched bit rates may cause periodic loss of data within the ATM networks, which results in corrupted bit stream in the receiver/decoder. Specific decoded video quality depends on the decoder design.

The process of modifying the bit rate profile of the input bit stream is called traffic shaping. The objective of the traffic shaping is to smooth out the burstiness of the ATM cell stream so that the resulting bit rate profile is more constant than that without traffic shaping. Existing methods to do traffic shaping include using a large buffer to smooth out the bit rate fluctuation, or to selectively drop ATM cells during high bit rate period. These methods were originally designed for connections carrying data streams or non-real-time multimedia bit stream. In the case of using large buffers, data bit stream is not sensitive to large delay variations. In the case of selective cell dropping, higher layer communication protocols will retransmit the lost information at a later time. However, in the case of transporting real-time compressed video, none of the method is acceptable because of the tight constraint on the end-to-end delay variation. For example, when ATM networks are used to transport MPEG-2 transport stream, the end-to-end jitter typically shall not be more than 1 millisecond. The use of rate converter as traffic shaper will solve exactly this problem.

Within ATM networks data loss may also occur when there is not enough channel bandwidth to send all of the ATM cells. In this case, ATM cells may be dropped from the overflowing buffers. If the bit stream carried in the connection complies with the connection agreement, such event will occur very infrequently and falls within the bounds of the quality of service constraints.

Also, it is important to point out that in general compressed video bit streams are generated by either real-time encoders or pre-compressed video server storage systems, which are likely to be in a remote site, away from the network facility itself. This implies that in general it is difficult to encode the video signal with a resulting bit rate profile tailored to the connection bandwidth available from the ATM network.

ATM network protocols are under intense international standardization effort and several industry wide interoperable specifications have been produced, including the one specific on means to carry MPEG-2 transport streams over ATM networks using ATM Adaptation Layer 5 (AAL-5).

Therefore, there is a need for a system and method for transmitting digital video information over data channels, that is simple to implement and has smaller delay, and can match the input bit rate to the channel bandwidth, resulting in a dramatically reduced bit error rate.

SUMMARY OF THE INVENTION

The present invention overcomes the deficiencies and limitations of the prior art with a system and method for converting a bit stream of a given bit rate to a different bit rate for reliable transport over communication channels. In various embodiments, the present invention includes: transmission of a compressed bit stream over Asymmetric Digital Subscriber Lines (ADSL) with rate adaptive capabilities (RADSL); transmission of a compressed bit stream over Asynchronous Transfer Mode (ATM) networks; flexible sharing of bandwidth of common communication channels among compressed bit stream and data traffic (including, but not limited to, data stream based on the ATM protocols or TCP/IP protocols, etc.); and statistical multiplexing of MPEG-12 transport streams.

A preferred embodiment of the system of the present invention comprises: a bit rate converter, a transmitter, a physical medium, and a receiver. The bit rate converter is preferably coupled to receive an input signal that is a video bit stream. The bit rate converter adjusts the bit rate of the input signal to match the communications channel and then outputs the bit stream to the transmitter. The transmitter is in turn coupled to the receiver by the physical medium. The transmitter sends the bit stream over the medium to the receiver, where the bit stream is received. Thus, the system of the present invention advantageously eliminates the need to decode and encode the bit stream before transportation over the channel. The bit rate converter eliminates the need for decompression and compression and preferably comprises: a separation unit, a decoder and extractor, a plurality of modification units, an encoder and a combining unit. The bit rate converter essentially adjusts the bit rate by making modifications to the video data portion of the bit stream. The bit rate converter first separates the video data portion of the bit stream and then decodes and extracts the video data. The data is then modified to change the bit rate, and then encoded and combined with the other signals that make up the bit stream.

A preferred method for transporting data over a communication channel comprises the steps of: converting a first bit rate of an input bit stream to a second bit rate, transmitting the bit stream at the second bit rate; and receiving the bit stream at the second bit rate. The converting a first bit rate of an input bit stream to a second bit rate preferably comprises the sub-steps of separating the bit stream into video, audio and data portions, decoding the video portion, extracting vectors and coefficients from the video portion, modifying the extracted data, encoding the modified data, and combining the encoded video data with the audio and data portions.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a block diagram of a prior art system for transmitting video data over a communication channel;

FIG. 1B is a block diagram of a prior art system for transmitting video data over a communication channel showing the encoding and decoding function in more detail;

FIG. 2A is a high level block diagram of one embodiment of a system constructed according to the present invention for transporting video data;

FIG. 2B is a block diagram of the preferred system for bit rate conversion according to the present invention, depicted using terms and reference numerals similar to the prior art system of FIG. 1B to show the advantages yielded by the present invention;

FIG. 2C is a block diagram of a first and preferred embodiment of a system, constructed according to the present invention, for transporting video data including a communication channel;

FIG. 3 is a block diagram of a second embodiment of a system for transporting video data integrated within the communication channel;

FIG. 4 is a first embodiment of a bit rate conversion device according to the present invention;

FIG. 5 is a second and preferred embodiment of a bit rate conversion device according to the present invention;

FIG. 6 is a block diagram of a system including a plurality of bit rate converters for sending a single stream of video data over a plurality of respective channels;

FIG. 7 is a block diagram of a system including a plurality of bit rate converters for sharing the bandwidth of a single communication channel;

FIG. 8 is block diagram of a system including a plurality of bit rate converters for performing a statistical multiplexing for use of a single communication channel;

FIG. 9 is a block diagram of a third embodiment of a system for transporting video data integrated within the communication channel, in particular, a rate adaptive asymmetric digital subscriber loop;

FIG. 10 is a graphical representation of the reference model used for the ADSL transceiver unit-Central Office and the ADSL transceiver unit-Remote terminal;

FIG. 11 is a block diagram of a system using the rate conversion device of the present invention as an input point for an asynchronous transfer mode (ATM) network;

FIG. 12 is a block diagram of a system integrating the rate conversion device of the present invention into an asynchronous transfer mode (ATM) switch; and

FIG. 13 is a block diagram of a system integrating the rate conversion device of the present invention into an ATM/ADSL communication device.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1A, a prior art system 10 for transmitting video data over a communication channel 19 is shown. The system 10 preferably forms a channel 19 using an encoder 14, a transmitter 16, a receiver 20, a physical medium 18 coupling the transmitter 16 to the receiver and a decoder 22. The encoder 14 receives an input bit stream 32 and compresses the input bit stream by encoding. The compress bit stream is then received by the transmitter 16 and output over the physical medium 18. The transmitter 16 can be any one of a variety of those known in the art for DSL networks or ATM networks. The signal sent over the physical medium 18 is received by the receiver 20 and input to the decoder 22. The decoder 22 restores the bit stream received by decompressing it into its original format.

FIG. 1B shows a block diagram of a prior art system for transmitting video data over a communication channel showing the encoding and decoding function in more detail. In particular, as shown, the encoding includes receiving raw video data and processing the raw video data with motion compensation 50, transform coding 52, quantization 54, and VLC encoding 56 to produce a compressed bit stream. The compressed bit stream can then, because of its reduced size, be transmitted over any one of a variety of prior art transportation systems 58. The decoding process is then applied to the compressed bit stream received from the transportation system 58 to obtain the original raw video images. The decoding includes VLC decoding 60, Dequantization 62, inverse transform coding 64, and motion compensation 66, all in a conventional manner.

FIG. 2A is a high level block diagram of one embodiment of a system 250 constructed according to the present invention for transporting video data. The system preferably comprises a compression unit 252, a bit rate converter 202, a transmission system 204 and a data formatting unit 258. The compression unit 252 receives video data and other data and produces a compressed bit stream. The compression unit may perform any one of a variety of types of compression including but not limited to MPEG compression, H.26X or H.32X compression for video conferencing, compression using proprietary video stream formats, and compression of non-real-time data bit streams. Those skilled in the art will recognize that the data formatting unit 258 is optional and provided only if additional data beyond the video data is being transmitted. The data formatting unit 258 may add such additional data by either providing it to the compression unit 252 as just described or by providing it directly to the transmission system 204 as also shown in FIG. 2A. The compression unit 252 provides a compressed bit stream to the input of the bit rate converter 202. The bit rate converter 202 advantageously adjust the bit rate to match the bandwidth of the transmission system 204. The bit rate converter 202 in its various embodiments will be described below in more detail, however, the bit rate converter 202 can perform conversion by adjusting or modifying the encoded bit stream syntax such as for the VLC decoding, the de-quantization, the inverse transform coding or the motion compensation. The output of the bit rate converter 202 is provided to the transmission system 204 which formats the data and transmits it over a physical channel (not shown). The transmission system 204 may be any one of a number of conventional transmission systems, including but not limited to ASDL, ATM/ADSL, ATM, ISDN links, Ethernets, public data networks, T1, T3, DS-3, OC-3, wireless/terrestrial networks, digital satellites, and digital cable networks, and particular ones are described below.

FIG. 2B is a block diagram of the preferred system for bit rate conversion according to the present invention, depicted using terms and reference numeral similar to the prior art system of FIG. 1B for ease of understanding and to show the advantages yielded by the present invention. In particular, the FIG. 2B is annotated with arrows to show the advantages of the present invention. As shown in FIG. 2B, the bit rate converter 204 includes a process of decoding, bit rate converting, and encoding in the compressed domain. However, based on the modification units (see FIGS. 4 and 5 below) used in the bit rate converter 204, the bit rate conversion process effectively follows one of the paths

specified by arrows A, B, C or D. Generally, motion compensation is most computationally expensive, transform coding and inverse transform coding are also quite expensive. In general, without special hardware to perform these functions, motion compensation and transform coding will take over 80%–90% of the overall decode-encode computation load. The key to a simplified rate conversion scheme according to the present invention is therefore to bypass some of these expensive steps. For example, in FIG. 2B, if we take the path B, motion compensation is avoided. If we take path C, both motion compensation and transform coding are eliminated. If we take path D, quantization steps are also eliminated, in addition to motion compensation and transform coding. Of course, if we take path A, the entire decoding and encoding processes are performed, resulting in the most flexibility and quality potential, at the cost of being most expensive. Each of these paths can be specified by the use of different modification units, **404**, **406**, **408**, **514**, **516**, **518** as will be described below with reference to FIG. 4 and FIG. 5.

While the present invention will now be described in the context of an Asymmetric Digital Subscriber Loop (ADSL) and ATM networks, those skilled in the art will realize that the present invention is applicable to a variety of other types of communication channels such as any xDSL includes ADSL, HDSL, VDSL, SDSL.

Asymmetric Digital Subscriber Loop, or ADSL, is a physical line code modulation scheme for transmitting digital bit stream over a single pair of plain old telephone system (POTS) grade twisted copper wires, that are usually noisy and are subject to outside interference. Several schemes have been developed to achieve high channel capacity of the said twisted copper wires. xDSL systems provide simple or full duplex raw bit pipes between the Central Office (CO) and the remote site receivers. The material content and the format of the bit stream or the protocols used by the connections being established by the bit pipe is immaterial to the xDSL system itself. In ADSL, the downstream link, from CO to remote site, has higher bandwidth than the upstream direction. Downstream channel capacity is typically up to 8 Mbps, and upstream channel capacity is up to about 1 Mbps; the actual channel capacity depends on the noise level of the wires and the distance between the transmitter and the receiver.

Because broadcast video quality can be achieved with compressed video, such as MPEG-2, at 3–6 Mbps, ADSL provides an ideal delivery scheme for compressed digital video and other high speed data connecting COs with remote sites, which can be either consumer subscribers or business establishments.

However, because of the variation in physical line conditions due to both the physical distance of the connection and the noise conditions of the lines, the ADSL transmission schemes do not specify channel capacity in either direction, rather the channel capacity is determined at connection set up time via channel initialization and training by the transceivers at the CO location and at the remote locations, in a conventional manner. The initialization and training process determines the proper coding configuration best matched to the current channel condition in order to achieve the maximum channel capacity. During the connection, due to change in line condition or due to loss of data, the transceivers may also re-initialize and retrain to settle on the new coding configuration.

In all the ADSL figures and discussions for the present invention below, it is important to point out that the ADSL channel is bi-directional, even though the present invention is described and shown by focusing on a single direction for ease of understanding. The present invention focuses on the transmission in a direction from a central office to a customer as shown in FIGS. 2C and 9 from **210** to **214**. In other words, the transmitter device (such as transmitter **906**) is also a receiver device in the reverse direction, from the customer to the central office (from **208** to **206**). For video over ADSL, the bit rate conversion over ADSL in the customer to central office direction appears pedantic but conceptually possible, though at a lower maximum bit rate. Still more particularly, if transmitter **906** in FIG. **9** is a transmitter as part of ATU-C (central office), then it must also be a receiver as part of ATU-C (remote). If box **906** is treated as part of an ATU-R then the end subscriber is sending bit rate converted video up-stream to central office.

Referring now to FIG. 2C, a first and preferred embodiment of a system **200** for transporting digital video data constructed according to the present invention is shown. The system **200** preferably comprises a bit rate converter **202** and a channel **204**. The channel **204** is further includes a transmitter **206** coupled by a physical medium **18** to a receiver **208**. This embodiment of the system **200** is particularly advantageous because, as can be seen from FIG. 2C, the need for the encoder and decoder is eliminated. The bit rate converter **202** simply adjusts the bit rate output to match the capacity or bandwidth of the channel **204**. More specifically, the bit rate converter **202** has an input coupled to line **210** to receive an pre-compressed signal of digital video data. The bit rate converter **202** adjust the bit rate at which the bit stream is provided to the transmitter **206**. The output of the bit rate converter **202** is coupled by line **212** to the input of the transmitter **206**. The output of the transmitter **206** is coupled by the physical medium **18** to the input of the receiver **208**. The physical medium may be any one of a variety of types, but is preferably twisted pair. The output of the receiver **208** is coupled to line **214** and provides the output signal which is also a compressed signal but with a different bit rate. As illustrated in FIG. 2C, the bit rate converter **202** and the transmitter **206** are separate devices or if performed in software separate modules.

Referring now to FIG. 3, a block diagram of a second embodiment of a system **300** for transporting video data integrated within the communication channel **300** is shown. In the second embodiment **300**, the bit rate conversion device or converter **304** is integrated with the transmitter **306** to form a single device **302**. Like the first embodiment, the second embodiment **300**, receives a pre-compressed signal on line **210**. Line **210** is coupled to an input of the bit rate conversion device **304**. The output of the bit rate conversion device **304** is in turn coupled to the input of the transmitter **306** by line **308**. The output of the transmitter **306** is likewise coupled to the physical medium **18** and the receiver **208**. This embodiment **300** is particularly advantageous because it allows integration of the bit rate conversion with the transmitter into a single high performance DSP device.

Referring now to FIG. 4, a first embodiment of a bit rate conversion device **202*a*/304*a*** according to the present invention is shown in more detail. The present invention advantageously uses bit rate conversion to match the rate of the bit stream to the capacity of the channel **204**. Bit rate conversion of compressed video bit stream refers to the process performed on a pre-compressed video bit stream which, when applied to the bit stream, results in a different bit usage than the originally compressed bit stream. In a typical scenario (see FIG. 2C), the new bit rate is smaller

than the original bit rate, but sometimes the resulting bit rate can also be greater than the original bit rate. When the digital video is first compressed, the encoder must assume a particular bit rate profile, whether it is constant bit rate (CBR) or a variable bit rate (VBR). The word "profile" refers to the fact that bit rate may not be constant, but variable under certain constraints, such as peak bit rate, average bit rate, minimum bit rate, etc. For example, a constant bit rate stream at 4 Mbps does not have the same bit rate profile as a variable bit rate stream at an average of 4 Mbps but has larger maximum bit rate and smaller minimum bit rate, respectively. In other scenarios (see FIG. 6 and 7), the compressed bit stream may be delivered to different transmission channels each having a different channel capacity, or the compressed bit stream may be further multiplexed with other bit streams to share the same channel capacity. For example, a compressed video stream at 6 million bits per second, or 6 Mbps, may need to be transmitted over a channel capable of delivering only, say, 5.5 Mbps. Therefore, if the same bit stream is transmitted over the channel, 0.5 Mbps must be removed before the transmission. As described earlier, arbitrarily removing the bits from the compressed bit stream is not acceptable. The bit rate conversion process is intended to remove bits from the compressed bit stream so that the resulting bit stream is still compliant to the given compression syntax, thus can be decoded by the receiver, albeit at a possibly lower quality than the originally compressed bit stream.

Even though a compressed bit stream typically comprises a combination, called a multiplex, of compressed audio, video and auxiliary data bit streams, the bit rate conversion process described in this invention refers specifically to procedures applied on compressed video bit stream. There are several ways to increase or decrease the bit rate of pre-compressed video bit stream. The present invention can alternatively use any one of the following methods for bit rate conversion.

1. Removing or insertion of filler packets/frames (in the case of MPEG-2 transport streams the filler packets are null transport packets);
2. Removing or inserting stuffing bits into the compressed video stream (in the case of MPEG, H.261, H.262 or H.263, stuffing bits can inserted or removed at the end of the encoded video frames);
3. Parsing and extracting the DCT coefficients, generate variable length codes, and re-combine them with the motion vectors in the originally compressed bit streams. In addition, reference frames may optionally be reconstructed in the frequency domain and re-quantization is performed.
4. Discarding data used to represent selected video frames and generate frame repeat information in the bit stream so that the resulting bit stream contains information to instruct the decoder to repeat the dropped frames to maintain continuous display;
5. First decode the bit stream into analog video frames and then encode the video frames back at a different bit rate suitable for transmission.

As best shown by FIG. 4, a first and preferred embodiment for the bit rate converter **202*a*/304*a*** comprises: a separation unit **400**, a decoder and extracter **402**, a plurality of modification units **404**, **406**, **408**, an encoder **410**, a combining unit **412** and a rate controller **430**. While the present invention will now be described as an apparatus composed of units, those skilled in the area will recognize that the present invention encompasses a method, process or software having as steps the actions performed by each unit and described below.

The separation unit **400** has an input and a plurality of outputs. The input of the separation unit **400** is coupled to line **210** to receive an input of pre-compressed digital video bit stream. The separation unit **400** preferably de-multiplexes the system layer stream, removing filler packets/frames as appropriate, to obtain the video bit stream, the audio bit stream and a data bit stream. The video bit stream is provided on a first output coupled to line **420**, the audio bit stream is provided on a second output coupled to line **422**, and a data bit stream is provided on a third output coupled to line **424**. Those skilled in the art will understand the operation of the separation unit **400**, based on the protocol being used for the bit stream. Based on the protocol, the bit stream can divided into the sub-streams according to the present invention.

The input of the decoder and extracter **402** is coupled to line **420** to receive the video signal from the separation unit **400**. The decoder and extracter **402** preferably parses all timing, programming and other auxiliary information and removes all stuffing data bits as appropriate. This parsing step produces a number of streams that in turn need to be decoded. In the preferred embodiment, three streams are produced, one for transform coefficients, one for motion vectors, and a final one for auxiliary information bits. The decoder and extracter **402** then decodes each respective stream with a suitable decoder, such as variable length decoding. Each of the decoded streams is provided on a respective output of the decoder and extracter **402**.

As shown in FIG. 4, the plurality of outputs of the decoder and extracter **402** are each coupled to a respective modification unit **404**, **406**, **408**. The modifications units **404**, **406**, **408** are used to reduce the number of bits needed for the transform (such as discrete cosine transform) coefficients, motion vectors, and other auxiliary information bits. As has been noted above, any one of a variety of methods can be used to modify the number of bits used to represent each portion of information for the three types, and thereby adjust the bit rate of the stream. The modification units **404**, **406**, **408** are controlled by the rate controller **430**. The rate controller **430** has an input and an output. The input of the rate controller **430** is coupled to line **434** to receive a control signal indicating the amount of conversion or the desired output bit rate for the bit rate converter **202*a*/304*a***. For example, line **434** may be coupled to line **912** to receive a rate value from a RADSL transmitter **906** in an ADSL embodiment or to line **1112** to receive a rate value from an ATM network **1106** in an ATM environment. The rate controller **430** provides a control signal to each of the modification unit **404**, **406**, **408** via line **432** (shown by diagram as a dashed box). The control signal specifies the amount of modifying each of the modifications units **404**, **406**, **408** performs to achieve the desired output bit rate from the bit rate converter **202*a*/304*a***. The modification units **404**, **406**, **408** may be similar to those described below for FIG. **5**.

The output of each of the modifications units **404**, **406**, **408** is coupled to the respective input of the encoder **410**. The encoder **410** preferably performs variable length coding of all the bits, and then outputs the encoded stream on line **426**.

The combining unit **412** has three inputs that are respectively coupled to lines **426**, **422** and **424**, to receive the encoded stream, an audio stream and a data stream. The combining unit **412** preferably performs multiplexing of the bits back into compliant bit stream and insert stuffing bits,

filler packets as appropriate. The output of the combining unit 412 is coupled to line 212 and forms the output of the bit rate converter 202a/304a. The output of the combining unit 412 provides a signal that is converted to match the rate of the channel.

Referring now to FIG. 5, a second and preferred embodiment of a bit rate conversion device 202b/304b according to the present invention is shown. The bit rate conversion device 202b/304b is adapted for use on a MPEG-2 transport stream. The second embodiment of the bit rate conversion device 202b/304b preferably comprises a separation unit 500, a de-multiplexer 502, a elementary stream bit parser 504, a DCT VLC decoder 506, a motion vector VLC decoder 508, an auxiliary information decoder 510, a rate controller 512, a plurality of modification units 514, 516, 518, a DCT VLC encoder 520, a motion vector VLC encoder 522, an auxiliary information encoder 524, a stream bit multiplexer 526, and a transport multiplexer 528.

The separation unit 500 first receives the pre-compressed video data stream. The separation unit 500 is similar as has been described above, and produces a video transport stream, an audio stream, and an data stream. The audio stream and data stream are output directly to the transport multiplexer 528 which recombines these streams with the rate converted video.

The de-multiplexer 502 is coupled to receive the video stream from the separation unit 500. The de-multiplexer 502 extracts a video elementary stream payload from the video transport stream and in turn sends the video elementary stream payload to the elementary stream bit parser 504. The elementary stream bit parser 504 receives the output of the de-multiplexer 502 and divides it into a transform coefficient component, a motion vector component, and an auxiliary information component. Each of these components is output to a respective decoder 506, 508, 510. For example, the discrete cosine transform (DCT) variable length coding (VLC) decoder 506 is provided for the transform coefficient component, the motion vector (MV) variable length coding (VLC) decoder 508 receives the motion vector component, and the auxiliary information decoder 510 receives the auxiliary information component.

As shown in FIG. 5, each of the modification units 514, 516, 518 is coupled to a respective decoder 506, 508, 510 as the source of information to be modified. The present invention also provides the rate controller 512 to control the bit rate at which the transport multiplexer 528 outputs data. The rate controller 512 preferably determines the bit usage of each video frame so that the resulting output bit stream maintains a desired bit rate profile. In the case of CBR video, the rate controller 512 ensures that the resulting output compressed bit stream can be delivered via a constant bit rate channel under the standard decoder buffer constraint. The present invention performs rate control by adjusting the quantization factor imbedded in the video bit stream, however, those skilled in the art will realize that other methods of rate control could be used. The rate controller 512 is preferably coupled to receive commands that specify the rate for the output stream, and therefore, the rate by which the modification units 514, 516, 518 must adjust the input data streams. For example, when the rate controller is used in the context of RADSL, the input to the rate controller 512 is coupled to line 532 which in turn is coupled to receive feedback from an RADSL transmitter or ADSL modem to control the target output bit rate such as the one shown in FIG. 9 (e.g., line 532 is coupled to line 912). In such an arrangement, the signal provided on line 532 is a value or rate for the modification units 514, 516, 518 to output data.

The rate controller 512 is shown diagramatically in FIG. 5 as being coupled to all three of the modification units 514, 516, 518 by control signal line 530. While the rate controller 512 has been described as being a discrete device, those skilled in the art will realize that the rate controller 512 could be software that provides a control signal to the modification units 514, 516, 518.

The modification units 514, 516, 518 can be used to provide a variety of bit rate conversions, and the present invention is not limited to the ones detailed below. The modification units 514, 516, 518 are used to modify the encoded bit stream syntax and bit usage. In addition to the functionality already discussed in the application, other functions the modification units 514, 516, 518 may perform include and involve modules, such as:

1) Selectively scaling or setting transform coefficients to zero (equivalent to filtering) using modification unit 514, then encoding the transform coefficients back into VLC using the DCT VLC encoder 520, to produce a different bit rate at the output of the transport multiplexer on line 305. This approach corresponds to taking the processing path D in FIG. 2.
2) selectively discarding entire coded frames using the decoders 506, 508, 510 and modification units 514, 516, 518 to produce a different coded video frame rate. This approach corresponds to taking the processing path D in FIG. 2.
3) Extracting and changing the quantization scale factors using the auxiliary information decoder 510 and the modification unit 518, and then using the changed quantization scale factors to encode transform coefficient back into VLC with the encoders 520, 522, 524, to produce a different bit rate usage at the output of the transport multiplexer on line 305. This approach corresponds to taking the processing path C in FIG. 2.
4) Completely decoding the bit stream and performing inverse transform coding (such as inverse DCT), however, preserving the same motion vectors extracted from the input bit stream using the MV VLC decoder 508, and then using the motion vectors to perform predictive motion compensated encoding, performing transform coding (such as DCT), followed by VLC coding with the DCT VLC encoder 520 to produce a bit stream at a different bit rate. This approach corresponds to taking the processing path B in FIG. 2. This approach would also require the addition of an inverse DCT module coupled between the DCT VLC decoder 506 and the modification unit 514, and the addition of a DCT module coupled between the modification unit 514 and the DCT VLC encoder 520. Essentially, in this approach, the modification unit 514 is performing image reconstruction and motion residual construction.
5) Changing the resolution of the video images by directly re-mapping the decompressed transform coefficients from one resolution to another using modification unit 514 and then encoding the resulting coefficients back into VLC using encoders 520, 522, 524. This approach corresponds to taking the processing path B in FIG. 2.
6) completely decoding the bit stream, adding low pass spatial filtering to the decoded digitized video images and re-encoding them back to compressed forms, to produce a lower bit rate. This approach corresponds to taking the processing path A in FIG. 2.

The outputs of the modification units 514, 516, 518 are in turn coupled to respectively to the DCT VLC encoder 520, the motion vector VLC encoder 522, the auxiliary informa-

tion encoder 524. Each of the encoders 520, 522, 524 codes the data back into the compressed format. The outputs of the encoders 520, 522, 524 are then combined by stream bit multiplexer 526, and then again combined with the audio and data by the transport multiplexer 528. Those skilled in the art will recognize from FIGS. 4 and 5 that the present invention can be applied to bit stream based on other transform schemes, and MPEG-2 is used only by way of example.

Referring now to FIGS. 6, 7 and 8, three systems where the rate converter/channel combination of the present invention is particularly advantageous will be described. The present invention focuses on schemes that combine rate conversion with the transmission channel. The combination allows lossless transmission of rate converted bit stream even when the original bit rate and available channel capacity are mismatched. The combination also enables flexible bandwidth sharing between the given bit stream and other data bit-streams.

Referring now to FIG. 6, a block diagram of a system 600 including a plurality of bit rate converters 604, 606, 608 for sending a single stream of video data over a plurality of respective channels 610, 612, 614 is shown. In some multimedia delivery systems, compressed video programs are delivered to numerous digital receiver/decoders via one or more digital transmission channels. In such multi-cast situations, the same compressed video bit stream 602, which has a predetermined bit rate R, must be delivered to different end receiver/decoders via different channels 610, 612, 614, and some of the channels 610, 612, 614 may not have a capacity sufficient to transmit the digital stream at the requested bit rate R. In these cases, the present invention applies the bit rate conversion process to the originally compressed bit stream so that the resulting bit rate is no more than the channel capacity. The system 600 preferably provides a respective bit rate converters 604, 606, 608. Each of the bit rate converters 604, 606, 608 is preferably adapted to convert the incoming original compressed bit stream to a bit stream with a rate that is appropriate for the respective channel 610, 612, 614 since each different channel 610, 612, 614 can have different capacity. For example, if the first channel 610 has a channel capacity R1, which is less than R, the bit rate converter 604 converts the original compressed bit stream to have a rate that matches the channel 610 capacity, namely R1. Similarly, if the second channel 612 has a capacity R2, where R2 is less than R but greater than R1, the bit rate converter 606 converts the original compressed bit stream to have a rate that matches the channel 612 capacity, namely R2. Finally, if the third channel 614 has a capacity R3, and R3 is equal to R, then the bit rate converter 608 simply passed the original compressed bit stream through the channel 614.

Referring now to FIG. 7, a block diagram of a system 700 including a plurality of bit rate converters 702, 704 for flexible sharing the bandwidth of a single communication channel 708 with other types of data streams is shown. In some multimedia delivery systems, extraneous bit stream data may arrive at the facility and must be multiplexed with the existing bit stream before being delivered to the receiver/decoder. However, the total available channel bandwidth may not be sufficient to accommodate the combined bandwidth requirement. In this case, bit rate conversion process may be applied to the originally compressed video bit stream so that the resulting combined bit rate is no more than the channel capacity. Such a system 700 includes a first bit rate converter 702, a second bit rate converter 704, a multiplexer 706 and a channel 708. The first bit rate converter 702 is

preferably coupled to receive a first original compressed video stream and output a rate modified bit stream to the multiplexer 706. The second bit rate converter 704 is preferably coupled to receive a second compressed video stream or data stream and outputs a second rate modified bit stream to the multiplexer 706. The multiplexer 706 combines the two inputs and outputs a single bit stream over the channel 708. According to the preferred embodiment of the present invention, the output of the first bit rate converter 702 and the second bit rate converter 704 are such that when they are multiplexed together they are less than or equal to the capacity of the channel 708. Therefore, by performing bit rate conversion on the two incoming streams, the present invention ensures lossless transmission since the channel capacity will not be exceeded. More particularly, the multiplexer 706 determines an intended bit rate profile for the first bit stream so that the converted bit rate is less than available channel bandwidth to allow the second data stream to take up any remaining bandwidth. The multiplexer 706 preferably includes a scheme that gives higher priority to the first bit stream so that when there is insufficient bandwidth, the second data bit stream is discarded. For examples, such a scheme is particularly advantageous where a time critical bit stream is provided to the first bit rate converter 702 such as real-time compressed video, and non time-critical data is provided to the second bit rate converter 704 such as a TCP/IP based data stream. Essentially, the lower priority data stream picks up the slack bandwidth left over by the high priority bit stream. The multiplexer 706 first determines bandwidth given to the real-time bit stream, it then uses the priority scheme to provide leftover bandwidth to the second data stream.

Referring now to FIG. 8, yet another application of the present invention is shown by the block diagram of a system 800 including a plurality of bit rate converters 802, 804, 806 for performing a statistical multiplexing for use of a single communication channel 810. In some applications, such as a satellite transponder, the analog spectrum of a coaxial cable is used to transmit digital video, or a wireless channel may be used to carry multiple compressed bit streams. In these cases, a multiplexing scheme must be used to allow logical sharing of the same channel bandwidth. If all of the bit streams participating in the multiplexing comply with the compression system layer standard, such multiplexing can be achieved within the compression system layer. Otherwise, the bit stream must be multiplexed using different schemes. The need for bit rate conversion arises when the sum of the individual bandwidths does not fit into the available channel capacity. In this case, the bit rate conversion scheme adjusts the compressed video bit stream in the multiplex such that the resulting multiplexed bit stream has a total bit rate no greater than the channel capacity. This process is called statistical multiplexing because in general the bit rate usage of an individual bit stream is not deterministic, but bit rate fluctuations compensate among different bit streams to achieve a constant channel bandwidth usage. As shown in FIG. 8, the preferred embodiment of such a system 800 comprises a plurality of bit rate converters 802, 804, 806, a statistical multiplexer 808 and a communication channel 810. Each of the bit rate converters 802, 804, 806 is preferably coupled to receive a respective original compressed bit stream and outputs a rate converted bit stream. Each of the bit rate converters 802, 804, 806 has its output coupled to an input of the statistical multiplexer 808 to provide the rate converted bit streams. Each of the bit rate converters 802, 804, and 806 also has another input coupled to receive feedback from the statistical multiplexer

808 via lines 812, 814 and 816, respectively. The statistical multiplexer 808 combines the three input bit streams into a single bit stream at its output. Through use of these feedback lines 812, 814 and 816, the statistical multiplexer 808 is able to provide a control input to selectively activate the bit rate converters 802, 804, 806 according to the available bandwidth in the channel 810. In the preferred embodiment of the present invention, the statistical multiplexer 808 outputs a data stream that is an MPEG2 transport stream and conforms to the standard MPEG2 format. The statistical multiplexer 808 may have a variety of embodiments and use different algorithms or bases to perform the multiplexing. For example, specific bit streams may be designated to have a priority in receiving a certain percentage of channel availability. Just as an example, video bit stream 1 may have a priority, and therefore be controlled via line 812 to have a minimum amount of rate conversion, while the other video bit streams 2 and 3, may have lower priorities, and therefore be subject to greater bit rate conversion using lines 814, 816. Furthermore, the statistical multiplexer 808 may also use time of transmission or scene content for video data to determine the priorities for channel usage, and use the control lines 812, 814, and 816 accordingly to apply various bit conversions rates to maintain maximum use of the channel capacity. In an alternate embodiment, the statistical multiplexers may be of the type constructed by General Instruments, DiviCom and other companies to control real-time encoders. While the system 800 is shown as multiplexing between only three input streams, those skilled in the art will recognize that any number of streams could be multiplexed. Finally, the output of the statistical multiplexer 808 is coupled to the channel 810.

Referring now to FIG. 9, a third embodiment of a system 900 for transporting video data integrated within the communication channel, in particular, for a rate adaptive asymmetric digital subscriber line (RADSL), is shown. The present invention is directed toward the integration of bit rate conversion schemes with ADSL rate adaptation feature to achieve relatively lossless transmission. Therefore, one key element of the invention is to create a synergy between the bit rate conversion of compressed video bit stream and the use of RADSL to transport compressed video bit stream, especially the transform coding based (such as MPEG) compressed video bit stream. Throughout the present application, the term bit rate conversion has been used so as not to preclude the possibility of upward bit rate conversion, but in general practical applications, the need for downward rate conversion far exceeds the need for upward rate conversion. Upward bit rate conversion can be achieved quite easily in different layers above the video compression layer, such as the transport layer (null transport packets), ADSL layer (bearer channel capacity configuration), etc.

As shown in FIG. 9, the third embodiment of the system 900 comprises an integrated bit conversion and transmitter device 902, a physical medium 18, a rate adaptive digital subscriber loop (RADSL) receiver 208 and initialization & reconfiguration logic 908. As shown, the integrated bit conversion and transmitter device 902 further comprises a bit rate conversion device 904 and a rate adaptive digital subscriber loop (RADSL) transmitter 906. The bit rate conversion device 904 has a data input and an output, and is coupled to receive a compressed bit stream at the input on line 210. The output of the bit rate conversion device 904 is coupled to the input of the RADSL transmitter 906 by line 910. The bit rate conversion device 904 also has a control input coupled to receive a control signal from the RADSL transmitter 906 by line 912. Thus, the conversion rate by which the compressed bit stream is reduced or increased is controlled by the signal from the RADSL transmitter 906. For example, the bit rate conversion device 904 may be of the type described above with reference to FIGS. 4 and 5.

Next, the RADSL transmitter 906 processes the bit stream from line 910 and outputs a bit stream over the physical medium 18. The RADSL transmitter 906 is of a conventional type (for example, the RADSL transmitter 906 may be a Copper Gold ADSL chip manufactured by Motorola, Inc. of Schaumburg, Ill.), and as will be described below with reference to FIG. 10; however, it is adapted to provide control signals to the bit rate conversion device 904. In particular, the RADSL transmitter 906 is modified from a conventional type by providing an output for passing along rate control signals received at initialization or during operation. A conventional RADSL transmitter is coupled to receive bit rate change control signals at either initialization or on-line mode. The control signal is in the form of bit rate value that the RADSL transmitter can handle. In one embodiment, this value is passed on to the bit rate conversion device 904 using line 912 to determine the targeted bit rate. Those skilled in the art will realize that the method for passing this rate control signal form the RADSL transmitter 906 to the bit rate conversion device 904 is implementation specific and may be done using any one of a number of conventional techniques.

The bit stream passes over the physical medium 18 to the input of the RADSL receiver 208. The RADSL receiver 208 is of a conventional type, and converts the information to a compress bit stream format which is output on line 214. As shown, the RADSL transmitter 906, the physical medium 18, and the RADSL receiver 208 are each coupled to initialization & reconfiguration logic 908 by line 914 to receive control signals as to how the data is to be coded and decoded before and after transmission over the medium 18. The line 914 is also used to test the medium to determine capacity of the channel or medium 18.

While the initialization & reconfiguration logic 908 is depicted in FIG. 9 as a logic block, those skilled in the art will recognize that the initialization & reconfiguration logic in box 908 may be a suite of signaling protocols exchanged between the RADSL receiver 208 and the RADSL transmitter 906 so that each device knows what is the maximum achievable bit rates in each directions, such as is now conventionally done is RADSL channels, and is an integral part of the ADSL standard.

RADSL adapts the maximum channel capacity to the physical twisted wire 18 line condition by adjusting the coding configuration. In the present invention, the bit rate conversion device 904 is integrated with the RADSL transmitter 906 and is used to adjust the output bit rate down from the input rate R to R_1 (typically $R_1 \leqq R$). This ensures that when the compressed video bit stream is received at the RADSL receiver 208 (decoder), the resulting bit stream maintains its data integrity and thus yields graceful quality degradation.

In the present invention, the channel capacity supported by the ADSL channel is advantageously conveyed to the rate conversion device 904 during the initialization stage. In addition, on-line adaptation and reconfiguration of the supported rate must also be conveyed to the rate conversion device 904. For example, with the ANSI (DMT) implementation, the maximum channel capacity the link can support at initial connection is signaled from the RADSL receiver 208 to the RADSL transmitter 906 in the R-B&G phase of the initialization process. In ANSI implementation, on-line adaptation and reconfiguration of bit rate are sig-

naled via the ADSL overhead control (aoc) channel and the channel capacity can be increased in minimum steps of 4 kbps at an interval of 17 ms to about 43 sec selectable by the RADSL receiver 208. This provides sufficient flexibility to the rate conversion device to properly setup the rate control parameters to perform the rate conversion.

Referring now to FIG. 10, a graphical representation of the reference model used for the RADSL transmitter 906 and an RADSL receiver 208 is shown. ADSL is becoming widely deployed by major telephone companies and one particular implementation of ADSL, the Discrete Multi-Tone (DMT), has been standardized by the American National Standards Institute (ANSI). In this standard, provisions are made to allow transmitter and receiver to perform initialization, training, optimum bit rate configuration, bit rate changes, etc. ADSL standard based on DMT is modeled as ADSL Transceiver Unit-Central office (ATU-C) and ADSL Transceiver Unit-Remote terminal (ATU-R). This model is shown in more detail in FIG. 10. From the model of FIG. 10, those skilled in the are will recognize that the RADSL receiver 208 has the same component blocks to perform the inverse function in ordered in reverse. The RADSL transmitter 906 preferably comprises a multiplexing and synchronization controller 1000, a error correction and interleaver 1002, a constellation encoder 1004 and a DAC and analog signal processor 1006. The bit stream is received by the multiplexing and synchronization controller 1000 which adds or removes control and synchronization information from the bit stream. The multiplexing and synchronization controller 1000 is coupled to the error correction and interleaver 1002 which performs error correction such as a cyclic redundancy checking and forward error correction. The output of the error correction and interleaver 1002 is in turn coupled to the constellation encoder 1004 which performs encoding on the bit stream. Finally, the bit stream in converted to an analog signal, processed and applied to the physical medium 18 by the DAC and analog signal processor 1006.

Yet another application of the present invention is to Asynchronous Transfer Mode (ATM) networks. The present invention also includes the concept of traffic shaping, used on ATM networks to change the bit rate profile of ATM cell streams through the bit rate conversion of compressed video and has tremendous value in all future ATM network implementations. Traffic shaping within the ATM networks using compressed video bit rate conversion is a crucial enabler of flexibly transport MPEG-2 video, as well as any other types of compressed video streams, over ATM networks. The present invention creates a synergy between the bit rate conversion of compressed video bit stream and the use of ATM networks to transport compressed video bit stream, especially the transform coding based (such as MPEG) compressed video bit stream.

Referring now to FIG. 11, another embodiment of the present invention as applied to an asynchronous transfer mode (ATM) network is shown. FIG. 11 is a block diagram of a system using the rate conversion device of the present invention as an input point for an asynchronous transfer mode (ATM) network 1106. In this embodiment, the present invention includes an integrated bit rate conversion device and ATM cell converter 1100 which in turn is coupled to an ATM network 1106. The ATM network 1106 is a conventional type known to those skilled in the art. The integrated bit rate conversion device and ATM cell converter 1100 further comprises a bit rate conversion device 1102 and an ATM cell converter 1104. The bit rate conversion device 1102 is similar to those that have been described above with reference to FIGS. 4 and 5. However, as shown in FIG. 11, the conversion rate is controlled by an external rate controller 1108 that is coupled to the bit rate conversion device 1102 by line 1110. In one embodiment, the external rate controller 1108 is logic or software that generates a control signal to specify a conversion rate that bit rate conversion device 1102 implements. The external rate controller 1108 can provide external commands for setting a target bit rate out of the bit rate conversion device 1102. The target bit rate out of the bit rate conversion device 1102 may be set based on several factors such as congestion condition within the ATM network 1106, connection level bandwidth negotiation between user and the network provider, etc. In yet another embodiment, the external rate controller 1108 receives control signals from the ATM network 1106 such as depicted in FIG. 11 by line 1112, for example from a remote network node. Such a remote node (not shown) can use the underlying conventional ATM signal protocol to provide rate control signals to the external rate controller 1108, as will be understood to those skilled in the art.

In this scenario, compressed video bit stream, such as MPEG-2 transport stream containing video programs, is being transported through the ATM networks from one location to another. In this case, rate conversion scheme is used with the ATM networks to accommodate the bit rate differences between available connection capacity from the ATM networks and the bit rate of the incoming MPEG-2 transport stream when the connection to be established is constant bit rate (CBR). This scheme is implemented at the ingress point of the ATM networks. Once the bit rate conversion device 1102 has converted the compressed video bit stream to a rate suitable for the ATM network 1106, the converted bit stream is provided to the ATM cell converter 1104. The ATM cell converter 1104 packetizes the converted bit stream into fixed sized data units or cells in a conventional manner. The ATM cell converter 1104 preferably performs the conversion from MPEG2 transport packets into ATM cells. In ATM terms, this function is called segmentation and reassembly (SAR), and is part of the ATM adaptation layer protocols (AAL). A typical implementation of the AAL function is in the form of an ASIC chip. The output cells are provided by the ATM cell converter 1104 to the ATM network 1106 and send to their destination.

FIG. 12 is a block diagram of a system integrating the rate conversion device of the present invention into an asynchronous transfer mode (ATM) switch. As shown in FIG. 12, the preferred embodiment of for the integrated ATM converter and bit rate conversion unit 1200 comprises an ATM cell de-converter 1202, a bit rate conversion device 1204, and an ATM cell converter 1206. In this embodiment, the integrated ATM converter and bit rate conversion unit 1200 is used to smooth the bit rate profile of the virtual connection at the ingress to the ATM network so that the resulting bit rate profile of the connection can be admitted by the ATM network. The integrated ATM converter and bit rate conversion unit 1200 can also be used to smooth the bit rate profile within the ATM network at point of traffic congestion so that buffers within the network will not drop cells at times of network congestion. This scheme is implemented within the ATM network, normally co-located with the ATM cross connection (ATM switches) devices where congestion condition requires re-allocation of bandwidth.

The ATM cell de-converter 1202 has an input and an output, and receives ATM cells for further distribution over the ATM network 1208. The ATM cell de-converter 1202 removes the data from its packetized format and restores it to a bit stream of compressed data, which is provided at the

output of the ATM cell de-converter 1202. The output of the ATM cell de-converter 1202 is coupled to the input of the bit rate conversion device 1204. The ATM cell de-converter 1202 can be any one of a number of conventional type devices know in the art. The bit rate conversion device 1204 is as has been described above in FIGS. 4 and 5. The bit rate conversion device 1204 changes the bit rate and provide the converted bit stream to the ATM cell converter 1206. The ATM cell converter 1206 takes the converted bit stream and then packetizes the converted bit stream into fixed sized data units or cells in a conventional manner. The output cells are provided by the ATM cell converter 1206 to the ATM network 1208.

Finally, referring now to FIG. 13, a block diagram of a system 1300 integrating the rate conversion device of the present invention into an ATM/ADSL communication device is shown. In this embodiment, the rate conversion scheme is used when compressed bit stream is carried as payload of the ATM cell stream, which in turn is transmitted over the RADSL device from the CO to the remote site. In this case, rate conversion is required not because of lack of connection bandwidth within the ATM networks or because of congestion conditions within the ATM networks. The rate conversion is required because the available bandwidth on the RADSL may be smaller than the bit rate of the compressed bit stream. In this case, the RADSL receiver must also perform the segmentation and re-assembly (SAR) of ATM cells before sending the video bit stream to the digital decoder.

As shown in FIG. 13, the system 1300 preferably comprises an ATM network 1302, an integrated ATM converter and bit rate conversion unit 1304, a RADSL transmitter 1306, a physical medium 18 and a RADSL receiver 1308. The ATM network is a conventional type known in the art, and provides ATM cells to the input of the integrated ATM converter & bit rate conversion unit 1304. The integrated ATM converter & bit rate conversion unit 1304 is similar to the type described above with reference to FIG. 12, and comprises an ATM cell de-converter 1310, a bit rate conversion device 1312, and an ATM cell converter 1314. The ATM cell converter 1314 is different than the one described above in FIG. 12 because it receives a control input from the RADSL transmitter via line 1316, in addition to providing the data stream to the RADSL transmitter via line 1318. In particular, as shown in FIG. 13, the signal line 1316 is preferably coupled between the bit rate conversion device 1312 and the RADSL transmitter 1306. The signal line is used to pass the rate control signals to the bit rate conversion device 1312 in a manner similar that described above with reference to FIG. 9. The RADSL transmitter 1306, physical medium 18 and RADSL receiver 1308 are similar to that described above with reference to FIG. 9. The notable differences are that the RADSL transmitter 1306 provides feedback information, and the RADSL receiver 1308 performs the segmentation and re-assembly (SAR) of ATM cells as has been noted above. Those skilled in the art will recognize that FIG. 13 describe the transmission of data only in one direction from 1302 to 1308, and that the RADSL transmitter 1306 and RADSL receiver 1308 are actually transceivers for transmission of data and video in the opposite direction similar to conventional RADSL channel. For such a reverse direction from 1308 to 1302, FIG. 13 could also include a second integrated ATM converter & bit rate conversion unit 1304 (not shown).

While the present invention has been described with reference to certain preferred embodiments, those skilled in the art will recognize that various modifications may be provided. For example, the present invention may be used to perform bandwidth sharing, despite the fact that the available bandwidth from the transmission facility, which includes but is not limited to, xDSL, ATM, wireless channel, is sufficient to send the incoming compressed bit stream. In general, for data traffic, such as TCP/IP based traffic, the data bit rate cannot be determined. In addition, the video bit stream may not have constant bit rate, therefore, the resulting total bandwidth cannot be determined before the connection is established. The application of bit rate conversion, however, will ensure that the resulting total bandwidth will always be less than the total available channel bandwidth. To this end, some kind of priority scheme must also be used to ensure that no video data is lost. Specifically, when the total input bit rate exceeds the channel capacity, TCP/IP based data packets must be discarded by the transmission facility to ensure packets containing video data is not lost. Therefore, there is a trade-off between how much bit rate reduction should be performed to the video bit stream, which results in graceful degradation of video quality, and how much throughput should be made available to TCP/IP based data streams. These and other variations upon and modifications to the preferred embodiments are provided for by the present invention.

What is claimed is:

1. An apparatus for modifying a bit rate of a bit stream to use an available bandwidth of a channel, the apparatus comprising:

a bit rate converter having an input, a control input and an output, the input coupled to receive a first bit stream with a first bit rate, the bit rate converter for converting the first bit stream to a second bit stream having a second bit rate, different from the first bit rate, the second bit stream being provided at the output of the bit rate converter; and

a transmitter having an input, a control output, and an output for transmitting data over the channel, the input of the transmitter coupled to the output of the bit rate converter to receive the second bit stream, the output of the transmitter coupled to the channel, the control output of the transmitter being coupled to the control input of the bit rate converter to send a control signal indicating a value for the second bit rate, the transmitter sending the second bit stream over the channel.

2. The apparatus of claim 1, wherein the second bit rate is less than the available channel bandwidth.

3. The apparatus of claim 1, wherein the transmitter is an xDSL transmitter that allows reliable transmission of the second bit stream and wherein the channel is a twisted copper wire.

4. The apparatus of claim 3, wherein the xDSL line condition determines the second bit rate.

5. The apparatus of claim 3, wherein the channel includes a physical medium and an xDSL receiver, the physical medium coupling the xDSL transmitter to the xDSL receiver.

6. The apparatus of claim 5, wherein the xDSL is a rate adaptive digital subscriber loop (RADSL) and the apparatus further comprises initialization logic coupled to the xDSL transmitter, the physical medium and the xDSL receiver for determining the available bandwidth of the channel and for providing a rate control signal to the xDSL transmitter indicating the available bandwidth of the channel, and wherein the xDSL transmitter provides the rate control signal to the bit rate converter.

7. The apparatus of claim 1, wherein the transmitter is an RADSL transmitter that includes a multiplexer and synchro-

nization control, an interleaver, a constellation encoder, and a DAC and analog signal processor coupled in series.

8. The apparatus of claim 1, wherein the transmitter includes an ATM cell converter, the channel is an ATM network, and the second bit rate is about equal to an available connection capacity from the ATM network.

9. The apparatus of claim 8, wherein the apparatus further comprises an external rate controller having an output for providing a rate control signal specifying a desired bit rate, the output of the external rate controller coupled to the control input of the bit rate controller.

10. The apparatus of claim 8, wherein the external rate controller has an input coupled to the ATM network to to receive a signal indicating a connection capacity of the ATM network.

11. The apparatus of claim 8 further comprising an ATM cell de-converter having an input and an output, the input of the ATM cell de-converter coupled to receive ATM cells, the output of the ATM cell de-converter coupled to the input of the bit rate converter, the ATM cell de-converter for converting ATM cells to a compressed bit stream.

12. The apparatus of claim 8 wherein the ATM cell converter includes an ATM segmentation and re-assembly device.

13. The apparatus of claim 8 further comprising:

an RADSL receiver having an input and an output, the input of the RADSL receiver coupled to a physical medium included in the channel.

14. The apparatus of claim 1 wherein the bit rate converter further comprises:

a decoder and extractor having an input and an output for decoding data streams and extracting timing and programming information;

a modification unit having an input and an output for changing the number of bits in the bit stream, the input of the modification unit coupled to the output of the decoder and extractor; and

an encoder having an input and an output for performing coding on a bit stream, the input of the encoder coupled to the output of the modification unit.

15. The apparatus of claim 14 wherein the decoder and extractor further comprises:

a demultiplexer having an input and an output for extracting a video elementary stream; and

an elementary stream bit parser having an input and an output, the input of the elementary stream bit parser coupled to the demultiplexer, the elementary stream bit parser for dividing the video elementary stream into components, the output of the elementary stream bit parser coupled to the modification unit.

16. The apparatus of claim 14 wherein the modification unit further comprises:

a first modification unit for reducing the number of bits needed for discrete cosine transform coefficients;

a second modification unit for reducing the number of bits needed for motion vectors; and

a third modification unit for reducing the number of bits needed for auxiliary information.

17. The apparatus of claim 14 wherein the encoder performs variable length encoding on the bit stream received.

18. The apparatus of claim 14 wherein the bit rate converter further comprises:

a separation unit having an input and a plurality of outputs for dividing the bit stream into a plurality of sub-bit streams, at least one of the plurality of outputs of the separation unit coupled to the input of the decoder and extractor for processing by the decoder and extractor; and

a combining unit having a plurality of inputs and an output for combining a plurality of sub-bit streams into a single bit stream, at least one input of the combining unit coupled to the output of the encoder.

19. An apparatus for bandwidth sharing between a first stream and a second stream, the apparatus comprising

a first bit rate converter having an input and an output, the input of the first bit rate converter coupled to receive the first stream, the first bit rate converter for changing a bit rate of the first stream to a first bit rate;

a second bit rate converter having an input and an output, the input of the second bit rate converter coupled to receive the second stream, the second bit rate converter for changing a bit rate of the second stream to a second bit rate; and

a multiplexer having a first input, a second input and an output, the first input of the multiplexer coupled to output of the first bit rate converter, the second input of the multiplexer coupled to output of the second bit rate converter, the multiplexer determining an intended bit rate profile for the first stream and allocating bandwidth to the first stream, and allocating any remaining bandwidth to the second stream.

20. The apparatus of claim 19 further comprising:

a transmitter having an input and an output for transmitting data over the channel, the transmitter having its input coupled to the output of the multiplexer to receive a mixed bit stream, the transmitter sending the mixed bit stream over the channel such that bit errors occur at a rate no more than a predetermined value.

21. The apparatus of claim 19, wherein the first stream is a compressed video bit stream and the second stream is a TCP/IP based data stream.

22. A method for modifying a bit rate of a bit stream to use an available bandwidth of a channel, the method comprising the steps of:

determining the bandwidth of the channel;

receiving the bit stream;

converting the bit stream to have a bit rate less than or equal to the bandwidth of the channel wherein converting the bit stream includes modifying data in the bit stream; and

transmitting the converted bit stream over the channel.

23. The method of claim 22 wherein the step of transmitting includes the step of sending the converted bit stream over a rate adaptive digital subscriber loop.

24. The method of claim 22 wherein the step of converting is controlled by a rate control signal from a RADSL transmitter.

25. The method of claim 22 wherein the step of determining the bandwidth of the channel is performed by initialization logic signaling an RADSL transmitter, a physical medium and a RADSL receiver.

26. The method of claim 22 wherein the step of transmitting the converted bit stream over the channel comprises ATM segmentation and re-assembly.

27. The method of claim 22 wherein the step of converting is controlled by a rate control signal from an ATM network.

28. The method of claim 22 further comprising the step of converting ATM cells to the bit stream before the bit stream is received.

29. The method of claim 22 wherein the step of transmitting the converted bit stream over the channel comprises the steps of:

converting the bit stream to ATM cells; and

sending the converted bit stream over a rate adaptive digital subscriber loop.

30. The method of claim 22 wherein the step of converting the bit stream to have a bit rate less than or equal to the bandwidth of the channel comprises the steps of:

decoding data streams and extracting timing and programming information;

modifying the number of bits in the bit stream; and

encoding the bit stream.

31. The method of claim 30 wherein the step of decoding data streams and extracting timing further comprises the steps of:

demultiplexing to extract a video elementary stream; and

parsing the video elementary stream to divide the video elementary stream into components.

32. The method of claim 30 wherein the step of modifying the number of bits in the bit stream further comprises the steps of:

reducing the number of bits needed for discrete cosine transform coefficients;

adjusting the number of bits needed for motion vectors; and

reducing the number of bits needed for auxiliary information.

33. The method of claim 30 wherein the step of encoding performs variable length encoding on the bit stream received.

34. The method of claim 30 further comprising the steps of:

separating a bit stream into a plurality of sub-bit streams for the steps of decoding, modifying and encoding; and

combining the plurality of sub-bit streams after decoding, modifying and encoding.

35. A method for bandwidth sharing between a first stream and a second stream, the method comprising the steps of:

bit rate converting the first stream to produce a converted first stream;

bit rate converting the second stream to produce a converted second stream; and

multiplexing between the converted first stream and the converted second stream based on an intended bit rate profile for the first stream and allocating bandwidth to the converted first stream, and allocating any remaining bandwidth to the converted second stream.

36. The method of claim 35 further comprising the step of transmitting the multiplexed data stream over a channel such that bit errors occur at a rate no more than a predetermined value.

37. The method of claim 35, wherein the first stream is a compressed video bit stream and the second stream is a TCP/IP based data stream.

* * * * *